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ADP MASTER PLAN

Volume III

January, 1979

COMPUTING IN COLORADO HIGHER EDUCATION -- A REVIEW WITH RECOMMENDATIONS

Richard D. Lamm, Governor

Thomas H. Sheehan, Jr., Executive Director

Department of Administration

1876

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December 27, 1978

The Honorable Richard D. Lamm
Governor, State of Colorado
State Capitol Building
Denver, Colorado 80203

Dear Governor Lamm:

Attached please find a copy of the 1979 Automated Data Processing (ADP) Master Plan for the State of Colorado.

The 1979 ADP Master Plan was prepared by the Division of ADP in accordance with CRS 24-30-613. It continues the managed growth approach to ADP which was started in 1977. This approach to managed growth includes consolidation of several computer centers, improved data processing services to user agencies, and simultaneous achievement of efficiencies of operation.

The 1979 ADP Master Plan is published in four volumes. Volume I summarizes the overall status of ADP in Colorado and recommends implementation steps for fiscal year 1979-80. Volume II contains the fiscal year 1979-80 budget analysis. Volume III is a report prepared entirely by EDUCOM, an independent consulting organization, which outlines steps to improve data processing in higher education. Volume IV contains the recommendations of a State task force to improve data processing among agencies concerned with the administration of justice within the State.

I ask your endorsement of the 1979 ADP Master Plan and request your permission to continue implementation of the action steps specified.

Sincerely,

Tom Sheehan Jr

Thomas H. Sheehan, Jr.
Executive Director

THS/dc

Attachments

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COMPUTING IN COLORADO HIGHER EDUCATION --

A REVIEW WITH RECOMMENDATIONS

November 1978

EDUCOM Consulting Group
P.O. Box 364
Princeton, New Jersey 08540

This Report by EDUCOM corresponds to Volume III of the 1979 ADP Master Plan for the State of Colorado.

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EXECUTIVE SUMMARY

This Report is the outcome of a study by the EDUCOM Consulting Group of computing in Colorado State colleges and universities. During the course of this review a number of important issues have been raised:

- There are wide differences in the availability and quality of computing services among institutions of higher education in Colorado.
- Obsolete equipment is, in many cases, providing poor service at a high cost per unit delivered.
- Lack of suitable budgeting and accounting procedures imposes undersirable rigidities and discourages resource sharing.
- Lack of technical support and staff training has made it difficult for smaller institutions to improve their capabilities.
- A general skepticism exists that any significant improvements requiring substantial investments of funds will be made.
- A funding level that has remained even in real terms for seven years has contributed to a lag in updating equipment and an inability of Colorado colleges and universities to take advantages of current computing technology in educational, research, and administrative areas.

An analysis of computing capabilities and requirements shows that the old equipment in place at many institutions is not cost-effective, in some instances delivering computer services at ten times the cost of newer equipment. Adequate computing capacity has become an essential ingredient in academic and research programs; increased demands placed on administrators make up-to-date computing systems an equally critical requirement for administration. In a number of institutions current computing capabilities do not meet today's requirements.

Alternative governance structures were examined and compared to determine which would best fit the needs for improved planning and management for higher education computing in Colorado. The alternatives considered are:

- Independence by institution
- Independence by governing board
- A higher education computing coordinating group
- An independent, non-profit operating corporation

A previous plan recommended the formation of a non-profit corporation for the management of computing in higher education, but this plan has not been implemented. The findings of this Report indicate that such a corporation is unlikely to be a good solution for Colorado for the following reasons:

- The start-up costs, both financial and political, would be higher than those of other alternatives.
- It is unlikely that a single management group could remain responsive to a very diverse set of institutions. The possibility is strong that such a corporation would be dominated -- in perception if not in fact -- by the major insititutions.
- The potential economies of scale in hardware and operating costs are likely to be offset by diseconomies of scale in management and complexity.
- If the corporation did not succeed, the process of shifting to yet another form or organization would be difficult.

The recommendations of this Report are broken down into the following three groups:

1. Management and controllership practices

- Computing should be funded on a long-term basis, with provision for the carry-over of funds from year to year through the mechanism of treating computing centers as auxiliary enterprises.
- The full cost of computing should be reflected in all computing budgets, including the amortized value of the hardware.
- Institutions providing computing services to other institutions should be permitted to recover the full cost of providing these services; there should be no adverse impact on other aspects of the supplying institution's budget.
- Budgeting and accounting methods should allow for the establishment of joint ventures.
- Budgets for higher education computing should be considered separately from those of State agencies.

2. Correcting major deficiences

- There should be a replacement of the administrative computer at the University of Colorado-Boulder

- There should be an upgrade or replacement of the timesharing system at the Colorado School of Mines.
- There should be a replacement of obsolete computers at Adams, Fort Lewis, Mesa, Trinidad, and Western.
- Equipment should be added at other institutions where it would significantly improve productivity of current computers.

3. An Appropriate Coordinating Function

A computing coordinating group should be formed as a top-level component of the Department of Administration for the purpose of working cooperatively with all institutions of higher education in the areas of planning, budgeting, training, and multi-institutional acquisitions of hardware and applications software packages. This coordinating group should be guided by the two Presidents' Associations through a strong advisory board that represents all the institutions served. The group would have a director and a small professional staff of three to five persons. The annual budget would be from about $160,000 to $280,000, depending on the size of the staff and the scope of activities. The Coordinating Group would be responsible for:

- Developing comprehensive long-range plans for computing in higher education.
- Developing budgets for computing in higher education.
- Presenting the budget for computing in higher education to the Legislature's Joint Budget Committee.
- Encouraging and promoting resource sharing in higher education.
- Providing training for faculty in the use of computing in instructional programs.
- Providing a mechanism for staff improvements for the computer center personnel in smaller institutions.
- Providing coordination for multi-institution hardware acquisitions.
- Helping to define and acquire common software packages.
- Developing data communication plans that would allow for cost-effective network sharing.

The principal reasons for selecting this alternative are:

- It would combine the ingredients of user control and institutional autonomy with statewide cooperation and resource sharing.

- It is likely to receive strong support from Colorado colleges and universities.
- It is consistent with the experience of most other successful sharing arrangements.
- Although the cost of the new organization would be greater than the status quo, it would be less than that of an independent, non-profit corporation, both financially and politically.
- It would enable the higher education community to speak with a single voice to the Legislature, and would provide the Legislature with a focal point for establishing priorities and trade-offs.
- It would provide the important expertise that is required to serve the diverse computing needs for teaching and research in higher education, which are not found in the data processing services provided to state agencies.

I. INTRODUCTION

This document presents the results of a study of computing in Colorado public institutions of higher education, and makes recommendations for improving the quality and cost-effectiveness of this activity.

A Request for Proposal (RFP No. ADP-C-1) issued in May 1978 began the formal process that led to this Report. The RFP asked for an implementation plan for a computing "consortium" that had been considered in earlier planning stages -- an incorporated, not-for-profit, independently managed organization responsible for the delivery of computing services to colleges and universities. Early meetings with the director of the study and a steering committee expanded this initial scope to include other alternatives for organizing and managing computing services. This change in scope was critical, because the results of the study indicate that the kind of consortium implied by the language of the RFP would not be the best solution for Colorado.

Within the first week of the study, a pattern emerged that was to become more sharply defined as work progressed. It became obvious that there exist significant systemic problems that need to be resolved largely independent of any proposed organizational structure. This fact dictated the emphasis and focus of this Report and the recommendations that it contains.

II. THE CURRENT STATUS OF COMPUTING IN COLORADO HIGHER EDUCATION

A. Overview

Each public institution of higher education within the State has been visited one or more times. Statistical, technical, and budget data have been collected from each institution. Presidents, top administrators, and providers of computing services have expressed their goals, values, and hopes for computing, and have shared their concerns and their recommendations. At each institution, instructional, research, and administrative users discussed in detail their needs and experiences.

The information from all of these sources has been carefully analyzed. The picture that emerged provides a remarkably consistent pattern of the current status of computing in Colorado higher education. This pattern has been considered against the background of higher education computing in other states, advances in computing technology, and the changing and expanding role of the computer in business, government, and society in general.

The remainder of this section discusses the current situation from two perspectives, institution size (relative to computing requirements) and major management issues.

1. Status by institution size

Large or technically sophisticated institutions with large research components led in the introduction of computing to Colorado higher education. Their size, their technical excellence, and their multiple funding sources provided a relatively high degree of management and financial flexibility. By efficient use of their discretionary funds, they were able to introduce computing in support of their major programs. In 1978 these institutions find that they are not able to maintain their traditional computing leadership position in spite of very high degrees of institutional commitment and priority. The quantity of computing available relative to need has been decreasing, and in some instances has reached a stage where serious difficulties and diseconomies exist.

Medium sized institutions experienced a lesser relative demand in both the quantity and variety of computing resources. Their instructional programs were less demanding of computing resources, and the need to support sophisticated research was small. These institutions now have a growing requirement for improved computing. As the computer plays an ever more essential role in the world that graduates will enter, and as contemporary education generally embraces computer use, pressure develops not just for a greater quantity of computing but for an increase in its quality and variety as well. These institutions are finding it difficult to provide the kinds of computing support enjoyed by their counterpart institutions in many other states. Their missions require them to provide up-to-date instructional programs and to keep pace with the job market and future challenges for their graduates -- goals that are become increasingly dependent on the quality, variety, and accessibility of computing.

Smaller institutions across the State present a more complex picture. Some of them -- Trinidad, for example -- were early leaders and innovators in the use of computing for instruction or administration. Their faculty, administrators, and boards were able to identify imaginative and visionary applications of the new technology that contributed to their teaching mission. Even the early leaders have not been able to obtain sufficient support to exploit their head start. Several of the schools that were once leaders still have the very same equipment and techniques with which they began years ago. Other schools have received hand-me-down equipment more appropriate for a computing museum than a modern college or university. Several institutions operate machines almost extinct across the nation, with the result that students learn the wrong lessons and administrators lack the tools to respond to their own internal needs and the growing State and Federal demands for data.

2. Management issues

Lack of suitable budgeting and accounting procedures gives institutions inadequate control over their computing resources and imposes undesirable rigidities. Some of the problems are as follows:

- Though computing requires long-term committments to capital resources, it is funded on an annual basis, making it difficult to engage in orderly financial planning.
- The amortized capital cost of computing equipment is not included in institution budgets, resulting in a somewhat artificial requirement for periodic capital infusions that are beyond the ability of an institution to absorb in its ordinary budget in any one year.

- Capital requests for computing are presented through a channel relatively independent of other forms of financial and program planning, thus making it difficult for decision makers to reach informed judgments about the need for additional computing capacity.
- Computing in Colorado is budgeted as if it were an end in itself, while in fact it is a supportive and necessary component of the instructional, research, and administrative activities of higher education.
- Use of the Department of Administration (DOA) as a channel for budgeting and appropriation for computing has apparently convinced institutions that they can use their time more productively on issues other than computing during their formal budget presentation. This has probably resulted in a lower level of computing in higher education than would have resulted if each institution had been encouraged to make its own trade-offs between computing and other uses of resources.
- The isolation of computing budgets from other program planning inhibits an institution from using instructional or other funds to provide for this supporting function, even when instruction, research, or administration would be improved by the shift of funds.
- Negative financial incentives have discouraged the sharing of computing resources among institutions; in general, only the barter system or an altruistic committment to the common good has permitted sharing.
- Colorado institutions tend to believe that they have even less flexibility than they may really have; it is not generally recognized that operating funds committed to computing could be used to acquire more cost-effective modern equipment.
- A principal source of computer hardware, particularly for smaller institutions, has been equipment no longer of value to other State agencies. This equipment is frequently a financial burden and an obstacle to the acquisition of up-to-date resources.

Complex administrative and "political" relationships between the many parties interested in computing have made it very difficult to deal effectively with the provision of computing services within State institutions of higher education.

- Institutions believe that computing has been singled out as a centralized issue, even though this is inconsistent with the generally decentralized management structure in Colorado higher education.
- The Colorado Commission for Higher Education (CCHE) has not been -- and apparently does not wish to be -- a co-ordinating force in higher education computing. Furthermore, the Commission's entry into this role would not be welcomed by the institutions.
- The DOA consolidates the budgets for higher education computing. This is not done by persons who are part of, or experienced with, higher education. There is a tendency in DOA to treat higher education computing in the same way as State administrative data processing, although this is particularly inappropriate for instruction and research computing.
- Analysts from the Joint Budget Committee (JBC) of the Legislature typically do not have much direct contact with representatives of higher education during their process of making judgements concerning computing in higher education.
- The DOA, in exercising its important controllership function, has tended to focus on computing hardware rather than on the far more significant management topics of planning, budgeting, charge-back, incentives, sharing, and software development.

Lack of technical and marketplace information has made it difficult for smaller institutions to achieve and maintain high quality, up-to-date, and cost-effective computing. Some example's of such problems are as follows:

- Special academic computing software (such as WATFIV or WATBOL) capable of greatly increasing the efficiency and effectiveness of academic computing is widely used elsewhere, but is rarely found in Colorado.
- Information on the most cost-effective current hardware for academic use is not reaching potential users.
- Resources have not been made available for training faculty members to take advantage of the potential of the computer for improving instruction.

- Opportunities to exchange ideas with others, and to learn of the techniques in use at comparable but more technically advanced institutions, have been limited. Travel by computing center personnel from smaller institutions to conferences or training programs is relatively rare, even though access to current information is crucial in this rapidly changing field.

Computing capabilities offered to students have not kept pace with the requirements of the job market or the need for further education. Faculty members reported the following major concerns:

- Current graduates moving into Colorado industry, such as mining and energy, report that their student computing experiences did not prepare them for the advanced computer use in these fields.
- Graduates entering the teaching profession in Colorado have not had experience with computing of the quality now found with increasing frequency in secondary schools. This deficiency will put education graduates at a disadvantage in the 1980's and beyond.
- Small schools sometimes fail to attract and hold top caliber students who want access to high quality computing resources and courses that provide a follow-on to the computing experience that they have already had in high school.
- Undergraduate students who transfer from smaller institutions to larger ones, or who enter graduate schools, find that their backgrounds are not adequate in computing -- particularly if they are pursuing technical programs.
- Students who lack access to adequate instructional computing, such as business simulation models or engineering design programs, must resort to other learning methodologies that are often less efficient in the use of the students' time; as a result, they may not be able to progress to the more advanced material that their peers are studying elsewhere.
- Some students exposed only to obsolete equipment while in school may graduate believing that they have learned about computing, while in fact they may be ill prepared to deal with current technology and applications.

A general skepticism exists among higher education institutions that they can achieve any significant improvement in computing. They tend to cite the following evidence to justify their pessimism:

- Plans have been prepared almost annually for many years -- some have even been "accepted" -- but little has come of them and the problems they addressed persist today.
- The current planning study is seen by many as just the current excuse for not resolving even the most pressing and obvious computing problems in Colorado higher education.
- The consulting team was sometimes greeted by "Don't take this as a criticism of your abilities, but nothing will come of this. It never has."

B. Conclusion

Colorado ranks well down the list of states in both quality and quantity of computing in higher education, and well down the list in the cost-effectivness of its computing expenditures. Each of the problems identified above can be found in some degree in other states; Colorado, however, experiences more than its share of problems, and in greater severity, than most other states.

It would be wrong not to point out that a number of bright spots also exist in computing. Among them are the following:

- Some institutions have done an extraordinarily good job of offering service in spite of the handicap of old and inadequate equipment.
- Some institutions have found innovative ways to replace obsolete equipment with up-to-date equipment within their own resources.
- Some notable gains have been made in sharing both hardware and software, even when the formal incentives did not favor such sharing.
- One institution has offered its students and faculty proportionally as much access to effective computing as almost any institution in the country.
- The largest institutions of the State have avoided most of the difficulties experienced by the smaller institutions.

One of the most encouraging aspects of the situation is the growing recognition by senior officials that significant steps must be taken to correct a difficult problem. One of the causes of past inaction -- and the pessimism that this has generated -- is the lack of sufficient high-level attention to the matter; those interested in computing have not previously been able to persuade senior officials that a serious problem exists or, if one does exist, that a thoughtful remedy has been presented to them. It is the purpose of this Report to document the problems and to propose a practical solution that recognizes the realities of the Colorado environment as well as the exciting potential offered by computing technology.

III. AGENCY RELATONSHIPS AS THEY AFFECT COMPUTING

In the organization of Colorado public higher education, the post-secondary institutions of the State are governed by six separate governing boards:

- Regents of the University of Colorado
    - University of Colorado-Boulder
    - University of Colorado-Colorado Springs
    - University of Colorado Medical Center
    - University of Colorado-Denver
- Trustees of the School of Mines
- Trustees of the University of Northern Colorado
- State Board of Agriculture
    - Colorado State University
    - Ft. Lewis College
    - University of Southern Colorado
- Trustees of State Colleges
    - Adams State College
    - Mesa College
    - Western State College
    - Metropolitan State College
- State Board for Community Colleges and Occupational Education
    - Arapahoe Community College
    - Community College at Denver
    - Lamar Community College
    - Otero Junior College
    - Pikes Peak Community College
    - Trinidad Junior College

A. Governing Boards

According to Article VIII, Section V (II) of the State Constitution

"(2) The governing boards of the state institutions of higher education, whether established by this constitution or by law, shall have the general supervision of their respective institutions and the exclusive control and direction of all funds of and appropriations to their respective institutions, unless otherwise provided by law." This article sets the general framework within which computing activities must be organized and managed. A major result of this decentralized governance structure is the grouping of institutions according to educational mission and student constituency. An institution in one group is reluctant to be lumped with another group for the purpose of organizing computer services when its other activities are organized along different groupings. The research institutions with large graduate programs, for example, have different perspectives and needs than the community colleges.

While most aspects of program planning and institutional administration are the prerogatives of the separate governing boards, computer budgets tend to be dealt with on a statewide basis through the Department of Administration and the Joint Budget Committee. This exceptional treatment of computing creates problems of divided responsibilities and conflicting goals that has led to some of the State's current difficulties in computing.

B. The State Legislature

The principal point of contact for computer-related plans and budgets in the Legislature is the Joint Budget Committee. It is here that all plans and requests for funding are made both by institutional presidents and by the representatives of the Division of Automated Data Processing of the Department of Administration. The Joint Budget Committee faces the enormous task of going over line-by-line budgetary needs of all the agencies of the State, including the sixteen institutions of higher education that have been examined in this study.

Each institution includes in its budget a request for funds for computer-related services. The request also goes to the Division of ADP in the Department of Administration, which consolidates it with requests from other institutions of higher education and from other State agencies. These consolidated requests are then presented to the Joint Budget Committee. The work of the JBC is assisted by analysts who review budget proposals with great care, and exercise considerable judgment of their own in this process. This is true of computing as it is of any category of budgeting within the state.

The president of an institution may choose to include in his presentation to the Joint Budget Committee a statement about computing needs. In practice, however, this rarely happens. The president may have as little as twenty to thirty minutes to make his presentation. In that time he must bring to the attention of the Committee the highest priority needs on his campus. Usually broader programs must receive this priority attention; there is seldom time to deal with computing or other essential support programs. Futhermore, presidents perceive that there is little value in their presenting a case for computing services, because it would have very little effect on the subsequent handling of computing through the Department of Administration.

The Legislature has held real computing expenditures relatively level for the past five to seven years. One must conclude, therefore, that it feels that support for computing in higher education has been adequate. It may be that the Legislature is simply responding to the lack of a strong advocate for higher education computing within the Department of Administration, which (legitimately) does not regard advocacy for a particular constituency as part of its role. From the perspective of college and university personnel throughout the State, however, reasonable requests for upgraded computing resources are lost or ignored in the current budgetary process, with no one clearly responsible for -- or even very concerned about -- the solution of their problems.

Within the higher education community, the feeling has grown that computing services have declined below the level found in comparable institutions in other states. In response, the Legislature and the Joint Budget Committee have sought to correct the situation by achieving greater efficiency within existing budget levels. The Legislature looks to the Department of Administration and its Division of ADP to provide more cost-effective plans for computer services for higher education. One result was the establishment of a task force that produced a new set of recommendations as part of the ADP master plan published in January 1978. These recommendations were not adopted.

There is a widespread feeling among the persons we interviewed that the Legislature is not likely to approve new appropriations for computer resources until the higher education community can "get its act together." This desire on the part of the Legislature led to the preparation of an RFP for consulting services to review the requirements for computing and develop a set of recommendations for meeting the needs of higher education. Some feel that the Legislature is temporizing, putting off as long as possible any decision that would require spending more money; this in turn has led to concern that no major steps will be taken to improve the situation. Others, however, believe that the Legislature and the JBC would respond to a reasonable, coordinated plan and would authorize new expenditures if convinced that the higher education community as a whole would support the plan and implement it successfully.

C. The Department of Administration

The Department of Administration, acting through its Division of Automated Data Processing, has statutory responsibility for recommending to the Governor automated data processing plans, administering those plans, reviewing existing and future ADP applications, and providing technical assistance and maintaining ADP facilities for certain State agencies. Because it is responsible for budget requests for computer-related activities in colleges and universities -- just as it is for other State agencies -- the Division of ADP exerts a significant influence over higher education computing.

The computer budgets for higher education constitute more than half of the total State computing expenditures; it receives considerably less than its proprotionate share of attention and concern by the Division of ADP, however. Within the professional staff of the Division, no one has had direct experience in higher education, and only one person is primarily concerned with the needs of higher education. That person's role is to participate in the development of the annual ADP Master Plan; to be aware of, and concerned with, the requirements for computing on all of the college and university campuses; to review and approve or disapprove all requests for computer-related equipment, software, and other services; and to advise the Director of the Division of ADP and the Executive Director of the Department of Administration on all matters related to computing in higher education.

This is an overwhelming task for one person, inevitably leading to great frustration for everyone concerned. Given the magnitude of his responsibilities and the limited resources at his disposal, he has coped remarkably well in an unenviable situation. On the one hand, he is viewed as a primary focus of computing in higher education, and is looked to for solutions. The smaller institutions in particular regard him as the most effective link between the campuses and the Legislature, and therefore the most likely source of needed computing resources. On the other hand, he is able to wield only modest influence in improving computing resources. As a consequence, the Division of ADP and the Department of Administration are regarded by some members of the higher education community as being obstructive and bureaucratic.

For the past few years the Division of ADP has been playing musical chairs with computer equipment, shifting it from agency to agency and campus to campus. As upgrades are made in the equipment of the larger State agencies, the cast-off purchased equipment is passed on as hand-me-downs to other agencies and to colleges and universities. As a result, the typical age of computers at the smaller schools is ten or twelve years old, with some schools using equipment that was introduced in the early and middle 60's. In private industry, where strong motivations exist to be as efficient as possible, computing equipment is rarely retained this long.

The shuffling of old equipment from location to location, combined with a lack of a clear-cut mission on the part of the Division of ADP to encourage higher education to install more advanced and more cost-effective technology, has created a climate of discouragement, frustration, and a fatalistic view of the future among many computer center directors and college administrators. Where new and up-to-date equipment has been obtained, it appears to be due primarily to the effectiveness of the individual president in presenting his institution's case for additional computing resources, rather than from a lead role played by the Division of ADP. It is small wonder, then, that the higher education community views the Division of ADP with decidedly mixed feelings about its lack of a mission to solve campus computing problems.

D. The Colorado Commission on Higher Education (CCHE)

The CCHE is not viewed by the higher education community in Colorado as an appropriate place to lodge the responsibility for dealing with computing problems or promoting cost-effective and immaginative computing in higher education. Until several years ago the Commission had considerable influence over computing and, in fact, was responsible for allocating computing funds and operating a computing center in the Denver area. These activities were not viewed as successful by colleges and universities, and the responsibilities were eventually moved elsewhere (principally to the DOA).

One of the critical questions addressed by this study is the best organizational location for the responsibility for computing within higher education. Initially it seemed reasonable that the reporting position should be in an area related to education rather than to general administration. However, college presidents and other administrators throughout the State advised in every case that it would not be appropriate to establish the function within the Commission of Higher Education. Even those individuals with reservations about the effectiveness of the Department of Administration would prefer to keep computing with DOA rather than move it back to the Commission.

IV. COMPUTING CAPABILITIES AND REQUIREMENTS

A. Current Institutional Capabilities

Interviews were held and data were gathered regarding the computing capabilities at all of the State universities, colleges, and community colleges. To our knowledge, no previous attempt had ever been made to quantify in common terms the capacity and related costs of campus computers.

Comparing the budgetary levels and capacities of the different computers is exceedingly difficult and subject to misinterpretation. Each computer center has a unique hardware and software configuration, and follows its own set of operating procedures to meet its particular set of mission-related demands for computing. An analysis and comparison of such centers inevitably runs up against the "apples and oranges" problem -- i.e., the problem of quantifying and comparing unlike things.

The study team on this project, with the advise and assistance of other computing professionals, devised two indices giving figures of merit, or "power ratings," to the eleven principal computer configurations operated on campuses in Colorado. The first index has been developed to estimate the relative power of each configuration for "scientific" computation, and emphasizes processing speed; a second index was developed to estimate the relative power of each configuration for "business" data processing, which places greater emphasis on input/output capabilities. It should be stressed that these ratings compare the power of these computers to each other within each index -- i.e., when dealing with only one class of computing (scientific or business) at a time. Although the two indices still provide only a relatively gross estimate of capacities, they are considerably more accurate than would be a single index that combines scientific and administrative computing. The table below shows the result of the calculations for different systems.

Computer*	Power Ratings Scientific	Business
CDC 6400	412	275
CDC 172	213	180
CDC 171	161	156
DEC/10	138	113
HP 3000	60	69
IBM 370/145	41	105
DEC 11/34	36	80
IBM 370/138	28	65
IBM 360/40	7	33
IBM 360/30	2	11
IBM 360/22	1.8	9

To determine the amount and cost of computing capability provided to the various campuses, the power rating was multiplied by the clock hours each computer is run under its present operating schedule. This multiplication determined the number of total "power-hours" of computing available during the course of a year for scientific or business computing. For each computer the number of power-hours was divided into the total operating budget of the center to derive a cost per power-hour for that institution if all the work had been of the scientific type or all the work had been of the business type.

The inaccuracies of the comparative indices and the absence of the capital costs for most equipment make these measures fairly crude. Nevertheless, they do give a rough idea of two things: 1) the relative computer capacity being delivered, institution by institution; and 2) the relative cost per unit of that capacity. Needless to say, the indices do not give any indication as to the value that an institution has gained from its computing capacity, or the efficiency with which it is using the capacity.

The order of the listing of institutions is taken from the chart of organization of Colorado Public Higher Education. The budget figures used were those given as "on-going for 1978-1979" in the 1978 ADP Master Plan.

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*The power ratings for each machine take into account the specific hardware configuration (e.g., memory size) used in a Colorado institution.

1. University of Colorado - Boulder

Computer Center Staff: 92.8 FTE

Budget: $3,176,682 (both centers)

Equipment: a. Academic Center, 2 CDC 6400 Computers

	Business	Scientific
Power Factor:	275	412
Power-hours available:	4,510,000	6,756,800
Cost per PH:	$0.52	$0.35

Equipment: b. Administrative Center, IBM 370/145 Computer

Power Factors	105	41
Power-hours available:	861,000	336,200
Cost per PH:	$1.34	$3.44

2. Colorado School of Mines

Computer Center Staff: 15.2 FTE

Budget: $435,440

Equipment: DEC/10 Computer

Power factors:	113	138
Power-hours available:	751,450	917,700
Cost per PH	$0.58	$0.47

3. University of Northern Colorado

Computer Center Staff: 22 FTE

Budget: $603,180

Equipment: IBM 370/138 computer

Power factors:	65	28
Power-hours available:	273,000	117,600
Cost per PH	$2.21	$5.13

4. Colorado State University

Computer Center Staff: 76.6 FTE

Budget: $2,522,364

	Business	Scientific
Equipment: a. CDC 172 computer		
Power factors:	180	213
Power-hours available:	828,000	979,800
Equipment: b. CDC 171 computer		
Power factors:	156	161
Power-hours available:	1,248,000	1,288,000
Cost per PH (both computers)	$1.21	$1.11

5. University of Southern Colorado

Computer Center Staff: 15 FTE

Budget: $316,413

Equipment: IBM 360/40 computer

	Business	Scientific
Power factors:	33	7
Power-hours available:	207,900	44,100
Cost per PH	$1.52	$7.17

6. Fort Lewis College

Computer Center Staff: 6.5 FTE

Budget: $130,178

Equipment: IBM 360/22 Computer

Power factors:	9 1.8	
Power-hours available:	40,950	8190
Cost per PH	$3.18	$15.89

7. Adams State College

Computer Center Staff: 7 FTE

Budget: $125,844

Equipment: IBM 360/30 Computer

Power factors:	11	2
Power-hours available:	49,500	9000
Cost per PH	$2.54	$13.98

8. Mesa College

Computer Center Staff: 5.5 FTE

Budget: $158,289

Equipment: IBM 360/22 Computer

	Business	Scientific
Power factors:	9 1.8	
Power-hours available:	39,600	7920
Cost per PH	$4.00	$19.99

9. Metropolitan State College

Computer Center Staff: 13.2 FTE

Budget: $361,159 (estimated academic support: $126,000)

Equipment: Data 100 RJE Terminal (GGCC)
Harris RJE Terminal (UNC)
HP-3000

Power factors (HP-3000):	69	60
Power-hours available:	231,840	201,600
Cost per PH:	$0.54	$0.63

10. Western State College

Computer Center Staff: 7 FTE

Budget: $151,319

Equipment: IBM 360/30 Computer

Power factors:	11	2
Power-hours available:	33,000	6000
Cost per PH:	$4.59	$25.22

11. Arapahoe Community College

Computer Center Staff: 6 FTE

Budget: $99,818

Equipment: Data 100 RJE Terminal (GGCC)
UT-200 RJE Terminal (CSU)

	Business	Scientific

12. Community College of Denver

Computer Center Staff: 21.5 FTE

Budget: $441,194

Equipment: Data 100 RJE Terminal (GGCC)
3 UT-200 RJE Terminals (CSU)
2 Disk data entry systems

13. Lamar Community College

Computer Center Staff: 2 FTE

Budget: $37,932

Equipment: Comdata multiplexor connecting 5 terminals to Otero's DEC 11/34

14. Otero Junior College

Computer Center Staff: 3.5

Budget: $95,463

Equipment: DEC 11/34 computer

	Business	Scientific
Power factors:	80	36
Power-hours available:	240,000	108,000
Cost per PH	$0.40	$0.88

15. Pikes Peak Community College

Computer Center Staff: 10

Budget: $217,615

Equipment: IBM 360/40 Computer

	Business	Scientific
Power factors:	33 7	
Power-hours available:	205,920	43,680
Cost per PH	$1.16	$5.46

16. Trinidad State Junior College

Computer Center Staff: 3

Budget: $66,371

Equipment: 2 IBM 1401 Computers

Power factors: Too low to rate

The table on the next page shows the rankings of each institution by cost per power-hour based on the two different indices of computing power. Power-hour costs vary with the power of the computer, the number of hours of operation, and the operating budget of the particular center. Two conclusions that can be drawn from these numbers are: 1) older equipment delivers a unit of computing at a much higher cost than new equipment, and 2) the smaller institutions where most old equipment is located are getting much less for their money.

It can also be seen from the figures in the table that the relative ranking of a given computer depends to some extent on the intended application. For example, the DEC 11/34 ranks first in business computing and fourth in scientific computing. Similarly, the figures reveal some economies of scale within a given type of machine -- e.g., the CDC 6400 has a higher ranking than the smaller CDC 171 or CDC 172. Nevertheless, the dominant effect is the age of the equipment.

Cost per Scientific Power-Hour

1.	UC - Boulder (CDC 6400)	$ .35
2.	Colorado School of Mines (DEC/10)	.47
3.	Metropolitan State College (HP-3000)	.63
4.	Otero Junior College (DEC 11/34)	.88
5.	Colorado State University (CDC 171,172)	1.11
6.	UC - Boulder (IBM 370/145)	3.44
7.	University of Northern Colorado (IBM 370/138)	5.13
8.	Pikes Peak Community College (IBM 360/40)	5.46
9.	Univ. of Southern Colorado (IBM 360/40)	7.17
10.	Adams State College (IBM 360/30)	13.98
11.	Fort Lewis College (IBM 360/22)	15.89
12.	Mesa College (IBM 360/22)	19.99
13.	Western State College (IBM 360/30)	25.22

Cost per Business Power-Hour

1.	Otero Junior College (DEC 11/34)	$ .40
2.	UC - Boulder (CDC 6400)	.52
3.	Metropolitan State College (HP-3000)	.54
4.	Colorado School of Mines (DEC/10)	.58
5.	Pikes Peak Community College (IBM 360/40)	1.16
6.	Colorado State University (CDC 171,172)	1.21
7.	UC - Boulder (IBM 370/145)	1.34
8.	University of Southern Colorado (IBM 360/40)	1.52
9.	University of Northern Colorado (IBM 370/138)	2.21
10.	Adams State College (IBM 360/30)	2.54
11.	Fort Lewis College (IBM 360/22)	3.18
12.	Mesa College (IBM 360/22)	4.00
13.	Western State College (IBM 360/30)	4.59

B. Summary of Computer Service Requirements

1. Relative Expenditures

The demography of computing in Colorado favors the Front Range. The greatest numbers of students are to be found in the Denver area, Boulder, Greeley, and Fort Collins. The intensity of computer use correlates with enrollments to a degree, but is also a function of the quantitative nature of the academic and research programs. For example, the Colorado School of Mines has an unusually heavy demand for computation for a school its size because of its scientific and technical character. The table below shows the distribution of computing dollars within the State. From this it can be seen that the eight Front Range institutions listed in the left-hand column are getting 90% of the computing dollars.

Institutional Share of State-wide Computing Dollars (Budgeted 78-79)

Univ of Colorado-Boulder	29%	Pikes Peak Community College	2%
Colorado State Univ	23	Mesa College	1.4
Univ of Colorado-Other campuses	18	Western State College	1.4
Univ of Northern Colorado	5.5	Fort Lewis College	1.2
Community College of Denver	4	Adams State College	1.1
Colorado School of Mines	4	Arapahoe Community College	.9
Metropolitan State College	3.3	Otero Junior College	.8
Univ of Southern Colorado	2.9	Trinidad Junior College	.6

For each institution the overall computer budget was divided by the fiscal year enrollment anticipated for 1978-1979, taken from the CCHE statistics in its long-range planning document. The resulting ratio of dollars per FTE gives a rough measure of institutional commitment to computing as an integral part of the educational and administrative process.

Budgeted Computer Dollars per FTE Student (78-79)

Univ of Colorado-Boulder	$157
Colorado School of Mines	148
Colorado State University	141
Univ of Southern Colorado	68
Mesa College	55
Adams State College	51

Univ of Northern colorado	51
Pikes Peak Community College	50
Western State College	47
Community College of Denver	42
Fort Lewis College	42
Metropolitan State College	36
Arapahoe Community College	27
(The following three schools have less than 1200 FTE:)	
Lamar Community College	80
Otero Junior College	174
Trinidad Junior College	55

As might be expected, the three research-oriented institutions show an expenditure triple that of most of the teaching-oriented institutions. These intrinsic differences make it very difficult to compare the relative status of computing across institutions having widely different missions.

2. Estimates of Short-term Future Demand

The growth rate in use of academic and administrative computing varies with the size of the school and the type of service. For example, increases in use of timesharing where it has been available (CSM) have been as high as 32% per year. The estimated increase for computing for academic programs is currently about 25% per year overall, and for administrative support it is about 18% per year. These rates of growth may taper off to a lower but continuing increase even if FTE student population levels off or decreases slightly in the early 1980's.

The current growth in demand is constrained by a lack of available resources, according to most knowledgeable faculty members and administrators. Because of the capacity or technical limitations of the old machines, many attractive applications are not feasible.

The current ratio of personal services to equipment rental and maintenance budgets is almost exactly 2 to 1 in Colorado higher education. If the amortized value of the equipment itself were included, the ratio might be closer to 1.5 to 1. The trends in information processing are in the direction of lower hardware costs per unit of computing and higher personnel costs as systems become more sophisticated. This trend is masked somewhat in education by the fact that considerable time of faculty members and students is not included as part of the computer center budget. According to the 1978 ADP Master Plan, serious unmet needs exist for software development and maintenance and for training and staff support, requiring an increase in personnel of 18%.

V. UNDERLYING ISSUES IN ORGANIZING STATEWIDE COMPUTING

There are a great number of issues that should be considered in selecting a suitable solution to a particular computing management problem. Some of the issues are technical, some are economic, some have to do with management style or philosophy, and others deal with the particular context in which the problem exists. The interaction of these issues is such that no single solution meets every need; no solution, however successful elsewhere, can be imported in its entirety and expected to serve another location as effectively. Colorado higher education requires a solution tailored to its needs, structure, and environment.

Six of the many issues that received consideration when comparing alternatives and forming recommendations are discussed in the paragraphs that follow. They are included here because they came up frequently with educators across the State and because they may help to establish a common frame of reference for reading of the following sections.

A. Some Thoughts on Sharing

"Sharing" is a positive word, and evokes images of friendly cooperation and of increasingly positive ties; it suggests the recognition of values beyond one's local environment and of common benefits as each gains from the other. When sharing is discussed in the context of computing in Colorado higher education, however, it is more likely than not to bring strongly negative reactions from the institutions. There are several reasons why this is so:

1. Problems in sharing

It is difficult to share in great disparity. A very small institution has little to offer to a large one; _sharing_ would be a one-way process. The large "supplier" institution is likely to view sharing as an inconvenience, and the small institution views it as undesirable dependence.

A very large institution currently has little incentive to adequately serve a small one. The user of a few thousand dollars of computing from a multi-million dollar center cannot be given close personal attention when this would disproportionately penalize large users. The large supplier is geared to offering a variety of sophisticated services, and may not be well prepared to assist a user having only basic needs. The most successful examples of computing resource sharing tend to be among equals.

A problem experienced by an actual small user in Colorado illustrates the difficulties. In attempting to solve some tough problems face-to-face, the user travelled far to the computer center from which he was trying to obtain service. When he got there, he found that no one knew who he was, and so he was not allowed in the computer room. While such security measures are necessary standard procedures at a large institution (and apply equally to its own users, of course), they are very foreign to users on many smaller campuses. The user came to the problem with such a different perspective from the supplier that effective communication did not take place.

"Sharing" experience in Colorado has produced some bad results that tend to overshadow the good ones. Institutions served by the COTIE experiment have memories of poor experiences with this service. Remote hardware reliability was bad, communication lines were uncertain, the host system tended to quit at unexpected intervals (in some cases for several days), and the big supplier was unresponsive, particularly after the special NSF support funds expired. Service was poor enough that several courses and programs had to be dropped entirely.

Some negative sharing experiences elsewhere influence the reactions of some Colorado institutions. A number of faculty members and administrators reported that they had been employed elsewhere when one-way "sharing" was imposed with unfortunate results. In one example that was cited, a serviceable resource was taken away to be replaced by a presumably much improved capability. Unfortunately, the replacement system did not meet its promises, or even reach the previous level of service. This has not been an uncommon experience across the country when viewed (as is appropriate) from the user rather than supplier perspective.

It is difficult to share when coerced to do so against the best judgement of the parties involved. When sharing is imposed by an outside agency, such as a legislative body, the parties involved may lack a deep personal committment to make the arrangement work. Indeed, the opposite may exist when reluctant participants (perhaps subconsciously) do nothing to correct the inevitable problems that arise when new systems and operating procedures are introduced. Success is far more likely when real dollars are involved and the user becomes a voluntary customer with the freedom to choose the type and source of computing services.

The obligations of being a supplier of service are substantially far more difficult to manage than the provision of local service, and not generally understood by those who have not experienced them. Many institutions across the country have concluded that they can increase their outside revenue, without a corresponding increase in costs, by serving as a supplier to external users. Often such a bid to become a supplier is not accompanied by an improvement in support and "marketing" services. The result is generally unsuccessful, because outside users (especially the less sophisticated ones) usually require extra technical support, high-quality documentation, and support personnel motivated to satisfy their customers.

Hardware economies of scale -- one of the important motivations for establishing sharing arrangements -- are becoming less important as hardware costs decline sharply and minicomputers grow in economy and power. A dogma developed in an earlier era -- that a very large machine shared by many small users is the only economical way to compute -- tends to persist, and may lead to centralization even in situations in which technical advances favor some degree of decentralization (such as the provision of simple interactive computing for undergraduates).

Sharing tends to be difficult when resources are scarce. Many sharing arrangements that might otherwise have worked fail when there is simply too little capacity to be effectively shared. A supplier is reluctant to see a scarce resource tapped by additional users when there are already too many clamoring for service; a user is equally reluctant to have to depend on an overloaded resource not capable of providing quality service.

2. Sharing Opportunities

Although establishing successful sharing arrangements is difficult, there are many resources that can and should be shared, and many good opportunities for doing so:

Sharing of application development can offer substantial advantages to institutions that could not afford to develop all applications independently. This opportunity is not universal, but does exist for some applications among like or similiar institutions.

Sharing of a part of the hardware, software, or data base resources remains attractive for generally equal partners having similar needs. This may be particularly true for expensive special purpose resources or in circumstances where specialization in certain types of hardware or software cannot be economically replicated. It may also be true of natural groupings of like partners where communications and travel are not a major obstacle. Productive sharing could extend beyond the State's higher education community, to other government or educational entities (assuming that policies and controls do not preclude this).

Sharing of a needed specialized resource provided by an external supplier should be allowed if the resource cannot be economically supported locally. This may include access to certain academic applications or to special data bases useful in instruction and research. Such services could be made available through the implementation of a purchased package on a computer at a Colorado institution, which could then provide the service to other State institutions (e.g., by means of an internal communications network). Alternatively, a service might be accessed from a national center or network, with perhaps a single institution serving as the interface with the network; bibliographic search services, library cataloguing services, discipline-oriented national computing centers, and the EDUNET network are examples of such sharing.

Shared hardware and software acquisitions can lead to purchasing economies not available to a single institution. The economies include not only price discounts for a bulk purchase, but can also result in attractive economies in maintaining a single type of hardware or software package.

Sharing expensive support functions can be attractive. This includes training, systems software support, and system tuning equipment and expertise. The potential is much greater where there is some degree of standardizaton in hardware and software resources among institutions.

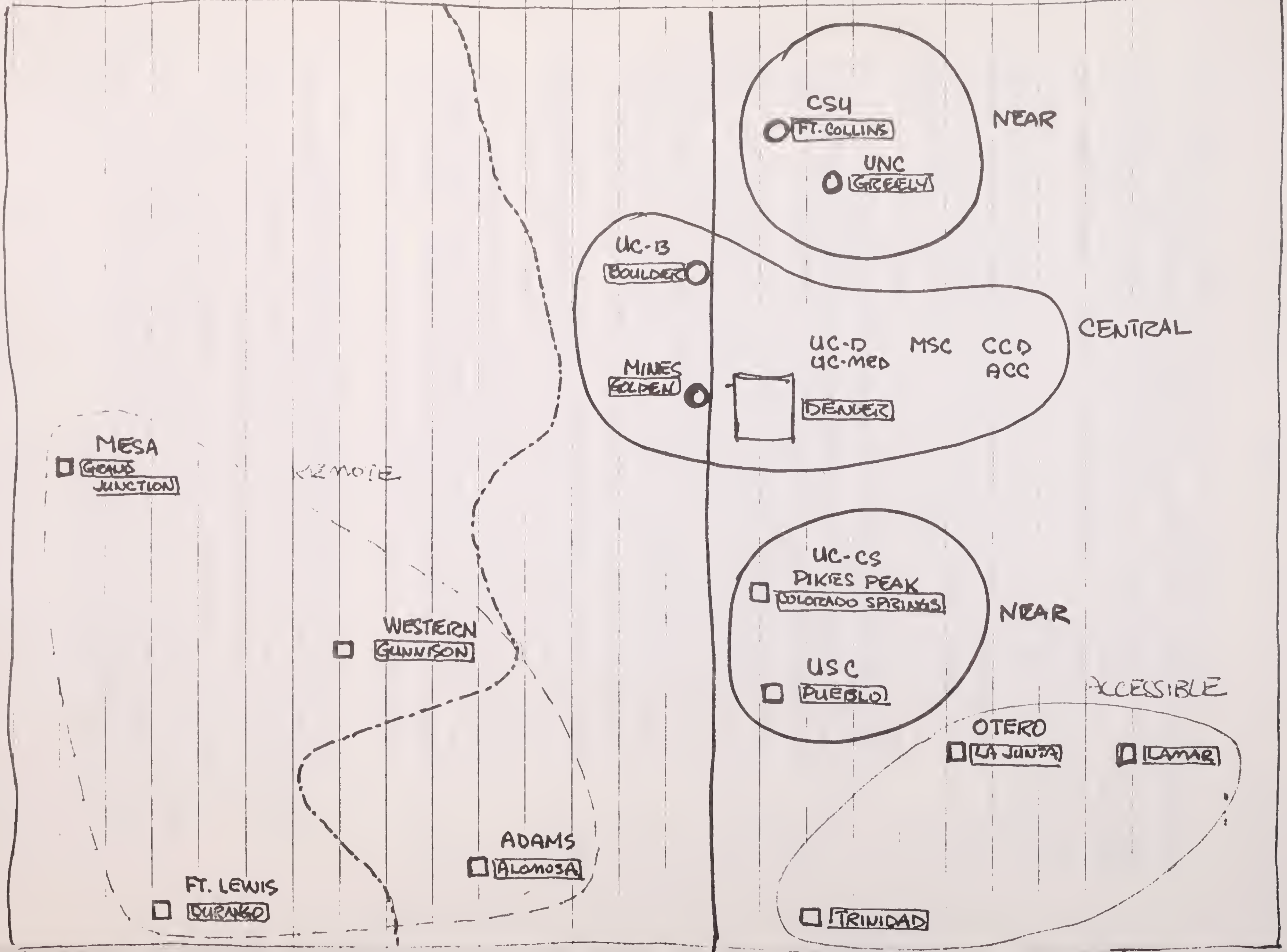
B. Geographic Considerations

The geographic distribution of institutions within the State inevitably influences the distribution of computing resources and the chosen governance structure.

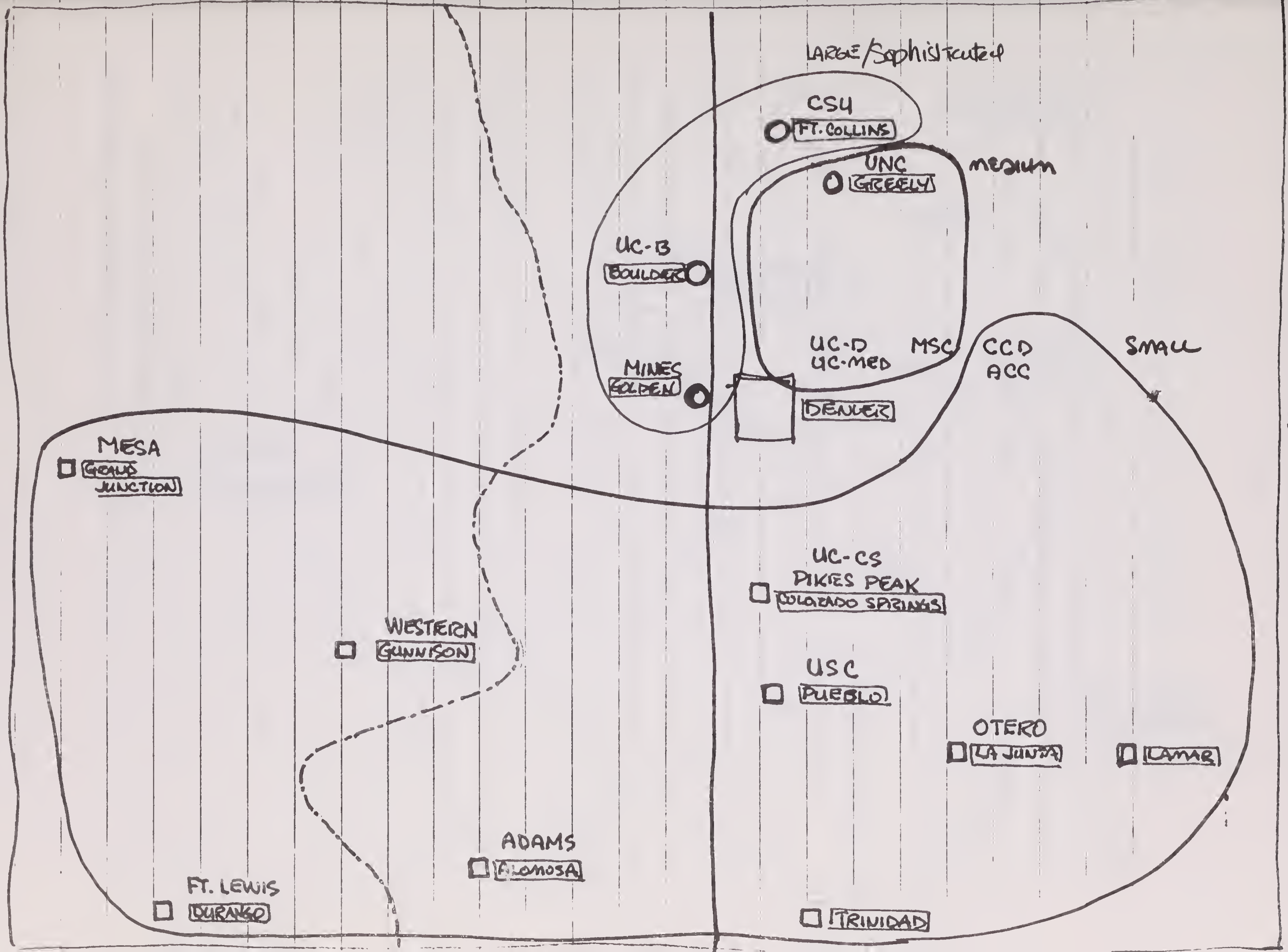
Map I shows the regions by their proximity to the Denver region, which is at the same time the major crossroads of communication and travel and the area of greatest concentration of computing activity within higher education, government, and industry. The Southeastern and Western Slope areas are particularly influenced by several geographical factors. Some of these influences are as follows:

- Travel is difficult and slow; during the winter months some passes are closed, and at other times tourists fill the highways and reserve most of the airline space. Getting together with other institutions in joint ventures is difficult and time consuming; face-to-face meetings must be minimized in setting up cooperative relationships. A second result of this remoteness is a tendency toward isolation -- isolation from the experiences of others and isolation from information that would help institutions to make better use of computing service and better choices about computing resources.
- Communications lines are significantly less reliable than those in the more central areas of the State; accordingly, there is reason to doubt that they are sufficiently reliable to provide the exclusive source of computing service (if this were otherwise desirable). This factor, among others, favors a significant local capability in addition to whatever resources are accessed remotely.
- Computer installations are sparsely distributed outside of the central areas, with the result that support for equipment by its vendor is limited. This factor will influence the choice of equipment vendors, and favors the kind of equipment that requires little maintenance or can be self-maintained (possibly with local stocking of spare critical components).

Map II divides the institutions of the State into regions by size and sophistication of their computing activities. This factor is relevant to the development of natural partnerships or relationships of two kinds: 1) cooperative undertakings by institutions having similar needs that permits organization on an equal-partner basis, or 2) customer/supplier relationships in which smaller institutions have only occasional needs for large-scale or special-purpose computing resources. The latter kind of relationship could also offer an opportunity for smaller schools to gain more rapid and thorough access to technical and application information.


CSU
FT. COLLINS
UNC
GREELY
NEAR
UC-B
BOULDER
CENTRAL
UC-D
UC-MED
MSC
CCD
ACC
MINES
GOLDEN
DENVER
MESA
GRAND JUNCTION
REMOTE
UC-CS
PIKES PEAK
COLORADO SPRINGS
NEAR
WESTERN
GUNNISON
USC
PUEBLO
ACCESSIBLE
OTERO
LA JUNTA
LAMAR
ADAMS
ALAMOSA
FT. LEWIS
DURANGO
TRINIDAD

II SIZE (COMMUTING)



Map III shows organizational relationships by geographic location. While this distribution does not result in particularly neat groupings of institutions, these relationships do offer another basis for the development of natural ties. The management structures of these groups could be accompanied by a corresponding computing management structure. The fact that each institution group responds to the same information requirements at the board level enhances the opportunity for administrative application sharing. Finally, in some but not all cases, the institutional missions within a group are sufficiently similar to suggest an additional basis for cooperation and sharing.

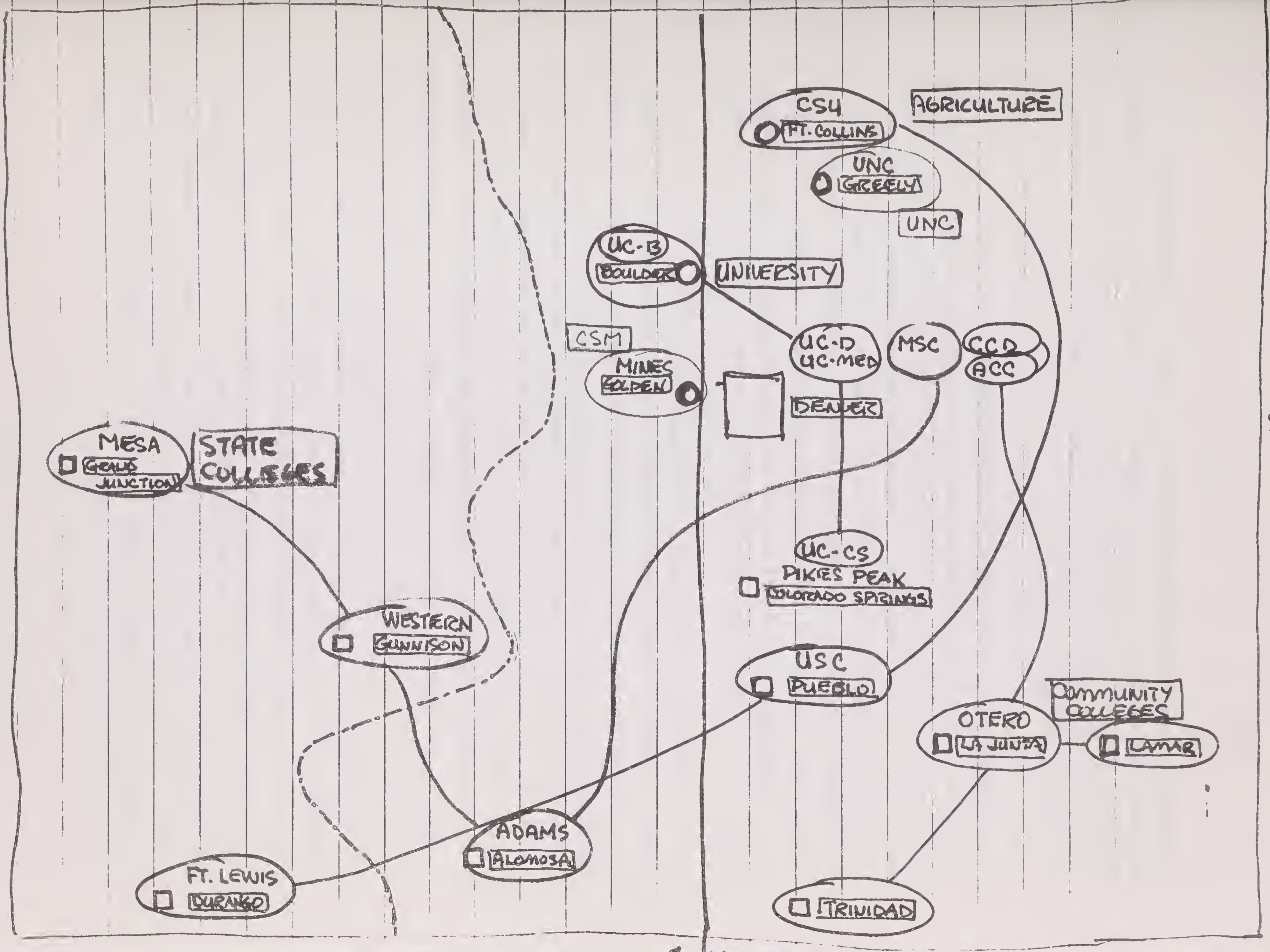
C. Hands-on Computing

Several Colorado institutions place very heavy emphasis on their ability to provide "hands-on" computing experience to their students. Although such experience is generally perceived as valuable, particularly at smaller schools, the meaning of the term is not uniform. Some see hands-on instruction as requiring a complete computer configuration with tapes, disks, and printers. Other believe it sufficient that students have practical operating experience with a remote job entry station connected to a large computer located elsewhere, or perhaps with a small mini- or microcomputer. In any case, however, the requirement for hands-on experience implies the availability of local equipment and a policy of fairly open access.

Computer managers at large institutions and users of large systems tend to discount this need as not very relevant to a college student's computing education. Their students, they believe, will generally not require hands-on access to computers in their professional pursuits after graduation; the few who do can quickly acquire the experience on the job. They thus tend to view such experience as more in the province of vocational training. They are probably right for most of their graduates, and are therefore justified in arguing against the need for hands-on experience in their institutions.

From some of the smaller institutions the perspective is quite different. A higher proportion of their graduates may choose careers in small organizations, and may become, at least for a time, the one-and-only computing expert in the organization, with the need to manage and plan the installation of the computer, program it, and operate it. Graduates report back to these schools that employers frequently ask for "practical" experience, in some cases

II ORGANIZATIONAL TIES



even where it may not be very relevant to their needs. A student who can claim a useful kind of hands-on experience may well be more successful in the job market than a more "theoretical" candidate. For this very pragmatic reason, the smaller institutions may also be right about the need for hands-on experience in computing education.

D. Interactive and other kinds of on-line computing

All of the institutions in this study emphasized the need to introduce, or to greatly expand, the use of interactive computing by students and faculty members; a similar need exists to provide on-line computing to users of administrative systems. Colorado's needs in this area are simply a manifestation of a national trend that is already providing a large return to those institutions that invested early in the required technology. This issue deserves some exploration here, lest these techniques appear to be just more complex or more expensive ways of doing the same thing now being done in batch mode.

Interactive computing is typically provided through a time-shared central computer accessed through a terminal and communications line. Though many users may be interacting concurrently with a single machine, each is served in a manner that makes it appear that the machine is dedicated to the individuals's own work. This kind of computing has several very attractive attributes for academic users, and is representative of an increasing common mode of computing that graduates must be prepared to use in their future work. It is extremely efficient for the development and execution of problem-solving programs. For example, some faculty members at CSM, where this service has been the mainstay for several years, believe it offers a 10 to 1 advantage over batch processing for complex problem solving. Timesharing provides a convenient means to distribute computing to classrooms and labs, the library, offices, and even dormitories. Its convenience and efficiency combine to bring about a positive qualitative change in the way in which computing is used. Timesharing is particularly efficient in applications calling for experimentation and trial-and-error searching for an improved solution. These are precisely the characteristics of much of instructional and research computing. Advances in computing technology now make it economically practical to expand the availability of timesharing: capable systems are available today for a cost in the neighborhood of $1 per terminal hour.

Interactive computing can also be provided through a small single-user computer system. No longer an extravagance, the single-user computer has become practical as a result of the dramatic reduction in the cost of electronic components that has occurred over the past decade. The equipment offerings in this area begin with the "personal" or "home" computers selling for a few hundred to a few thousand dollars and offered by Radio-Shack, Heathkit, mail order firms, and by retail computer stores. A few of these are already in use in Colorado higher education. At the "big" end of the spectrum are complete systems specifically tailored to academic needs, costing up to $10,000 -- still a remarkably low price by historic standards. An example of this part of the spectrum is found in the "Terak" computer, which with its $5000-7000 price tag and remarkable capabilities has already attracted the attention of several Colorado institutions. The one-on-one machines will play a major role in academic computing during the next few years. The larger institutions in Colorado have been the most sensitive to this development to date; the smaller institutions need to learn more about them.

Administrative on-line computing is also needed at most institutions. This mode of administrative computing gives the registrar or business manager direct access to the records and files needed in the conduct of business. Keypunching can be reduced or eliminated; instead, data are entered as part of the normal process of doing business, and errors that are detected can be corrected immediately by those familiar with the application. This provides improved accuracy, completeness, and timeliness. More importantly, it gives the manager responsibility for, and control over, the data that are essential to his operations.

E. Control of Computing Expenditures

Most of the attempts to control computing cost place undue emphasis on hardware and the hardware acquisition process. A focus on hardware made sense in the earlier days of computing when hardware costs constituted the majority of the total; this is no longer the case, however. Today the significant issues involve such matters as the choice of applications, the integration of the applications, and the development of software. These are much more difficult to guide and control. Controlling hardware would be attractive if, through this process, control could be exercised over the other factors, but unfortunately this is not the case.

Control over hardware in an environment of rapid growth in demand for capacity can cause serious penalties. Limiting the acquisition of hardware by this means may yield an apparent savings in the hardware part of the data processing budget, but the large (and often hidden) costs of inefficient use of personnel and failure to achieve academic objectives may be very much greater than the hardware savings. False economies of this kind are a special hazard at colleges and universities, where the time of faculty and staff (not to mention students!) is often treated as though it had a zero incremental cost.

VI. ALTERNATIVE GOVERNANCE STRUCTURES FOR COLORADO HIGHER EDUCATION COMPUTING

This section contains descriptions of the four structures considered for Colorado higher education computing. Each alternative is described, giving both its positive and negative attributes along with its governance and management characteristics. The alternatives considered are 1) independence by institution, 2) independence by governing board, 3) a higher education coordinating group, and 4) an independent operating consortium.

The descriptions that follow assume that the recommendations of part VII will be adopted, particularly those dealing with budgeting, funding, and establishing an inter-institution marketplace for computing and a focus of leadership under the guidance of the higher education community. In the absences of these fundamental ingredients for success, no option is likely to make a significant improvement in higher education computing in Colorado.

A. Independence by Institution

The clear choice of Colorado institutions themselves is a structure that would give them the ability to independently acquire and manage the computing resources best suited to their particular mission and requirements. Their preference for this alternative is a strong argument in its favor, because one of the most important ingredients for success in implementing any structure will be the support and committment it receives from the institutions that must make it work.

Independence would not mean that an institution could operate free of overall policy and budget constraints set by its board and the educational and government hierarchy of which it is a part. Nor does independence mean that each institution would "go it alone" without regard for the needs or capabilitites of other institutions. Indeed, given independence in an atmosphere of proper incentives and leadership, a great deal more useful sharing may occur than would be achieved through coercion.

Independence does mean that the institution has the freedom to choose which resources can be economically provided locally, and which can best be obtained from another institution or source. It allows the institution to join with another in forming a common computing center if that solution is economical and can provide the most effective service.

Such an approach has a number of positive attributes; among them are the following:

- Institutions are likely to support this structure, and will work hard to make it work; the institutions themselves will be likely to solve most of their own problems in using the computer.
- This solution provides the greatest degree of response to the special needs, programs, and attributes that make an institution unique; it supports the existing diverse nature of Colorado institutions of higher education, and encourages the rapid exploitation of new technologies.
- The solution is consistent with developments in computing technology, in which the traditional economies of scale have been largely superceded by economies of simplifications and specialization.
- This solution is consistent with the generally decentralized nature of higher education in Colorado.

Despite its attractive features, independence does have some negative attributes as well:

- Institutions tend to believe that this alternative is very unlikely to be accepted by the DOA and/or the Legislature, and are therefore skeptical that it could ever succeed.
- Several Colorado institutions may lack the managerial and technical skill needed to develop and operate a cost-effective computing activity.
- Undersirable duplication of resources and managerial effort would probably occur.
- Each institution, in making its own trade-off decisions regarding the use of its resources, may not necessarily act in the interests of the State or parties not closely involved in the decisions (e.g., students); for example, it might choose to develop its own software even if it could obtain equivalent (or better) software from another institution.

By its nature, activities under this approach are not centrally directed or orchestrated and cannot therefore be predicted in detail. Given implementation of the managerial and incentive changes recommended in Part VII of this Report, however, the following could be expected:

- Natural consortia would expand and develop: 1) The Otero/Lamar shared center would expand and could well extend to Trinidad. 2) A Western Slope consortium would very likely develop to better serve Mesa, Western, and perhaps Adams and/or Fort Lewis. 3) Adams could also elect to combine resources with another Alamosa facility. 4) The shared facilities in Denver would continue and could be extended to include academic timesharing services. 5) The School of Mines and the University would achieve a greater amount of sharing of their current resources and might well decide to cooperate on the acquisition of special-purpose equipment that they both lack at present (for seismic and satellite image processing, for example). 6) The Colorado State University/University of Northern Colorado exchange of services would be formalized and placed on a market basis.
- A greater number of application programs would be shared among like institutions (e.g., registration and other student records applications).
- Just as State data centers supply some higher education computing, higher education would very likely supply an increased amount of special kinds of services to State Government (timesharing, simulations, statistical analysis, graphics, and other services used in greater volume in education).
- Agreement would be reached by several institutions to focus on some common types of hardware, thus facilitating lower purchase prices and sharing in the area of costly systems software maintenance and tuning.

B. Independence by Governing Board

A structure that gives independence by governing board would place principal responsibility with each of the six independent boards or central administrations. Each board might, in turn, choose to delegate part of its responsibility to individual institutions where geography or mission favor such a move.

This approach already exists in large measure, even though it has not been formalized with respect to computing. It tends to be weakened by the controllership focus on individual institutions, and it is not fully reflected in the budget process. An explicit example of this structure was found in the University, where the management of major computing centers reported (until recently) to the Central Administration, with resources shared among campuses.

The positive attributes of this approach are:

- This structure, like the previous one, responds to the axiom that the degree of centralization or decentralization in computing should match the degree of centralization or decentralizaton in general management; any significant mismatch will greatly increase the chances of difficulty and failure.
- From both institutional and statewide perspectives, control over computing rests with a known quantity with whom regular channels of communication already exist for all other management purposes; the prospects for achieving trust and avoiding surprises are therefore high.

A negative attribute of this structure is the fact that some administrative reporting relationships contain institutions of very different size and mission, and with widely separated locations (e.g., the Board of Agriculture is responsible for the very large CSU and the smaller and geographically separated institutions at Pueblo and Durango).

This option would probably result in only small differences from the option of individual campus independence:

- A Western Slope consortium would more likely consist specifically of Mesa, Western, and Adams.
- Fort Lewis at Durango would be likely to continue to develop independently due to its remote location, but might choose to buy some services from a Western Slope consortium. Pueblo might develop similarly.
- Prospects for a Community College Consortium would be enhanced, although geographic ties would probably continue to be stronger than those of the formal organizational structure.

C. A Higher Education Computing Coordinating Group

The goal of a Higher Education Computing Coordinating Group is to balance the need for statewide planning and support for computing with the strongly-felt need for user control. It would provide joint planning, budgeting, and support among all higher education institutions, but would have no operating responsibilities. Such a Group would have its own charter and statutory authority, an advisory board drawn from higher education, a small staff, a director, and a budget. The staff would spend most of its time in support of work on individual campuses. The Director of the Group would act within guidelines established by a representative advisory board, and would also have a reporting relationship to the Executive Director of the Department of Administration.

1. Responsibilities

The Coordinating Group would be assigned the following tasks and responsibilities:

- Developing comprehensive long-range plans for computing in higher education.
- Developing budgets for computing in higher education.
- Presenting the budget for computing in higher education to the JBC.
- Encouraging and promoting resource sharing in higher education.
- Helping to define and acquire common software packages for use in higher education.
- Providing coordination for multi-institution hardware acquisitions.
- Providing training for the faculty on the use of computing in instructional programs.
- Providing a mechanism for staff improvements for the computer center personnel in smaller institutions.
- Developing data communication plans that would allow cost-effective resource sharing.

Such a consortium would not:

- Dictate individual institutional priorities.
- Own or operate computer or communications facilities.
- Act as a financial agent for the purchase of equipment.
- Produce software.

Under this alternative, most computing resources would be operated at the local campus level, with opportunities provided to purchase specialized resources from other Colorado institutions, regional computer centers, or national networks. A reasonable expectation for most institutions is that about 80 percent of their demand could be satisfied locally, while the remaining 20 percent would be obtained more economically from external sources.

2. Governance

The Coordinating Group would be created within the Department of Administration. It would be guided by a representative Advisory Board selected primarily from among the State institutions of higher education, with some outside members chosen for their knowledge of computing.

3. Organization

The Coordinating Group would be directed by a senior professional with wide managerial experience in computing and considerable knowledge of the needs of higher education. The person selected should view the role of the Group as one of leadership through suasion and demonstrated helpfulness to the campuses, and would not aspire to become the "czar" of computing in Colorado higher education. Sensitivity to individual institutional needs and concerns should be a paramount interest.

The staff of the Coordinating Group would be kept small, in the range of three to five professionals, who would be selected to provide the following skills and contributions:

- Technical and financial planning.
- Budget preparation and record keeping.
- Effective advocacy with State officials for improvements in computing in Colorado higher education.
- Development and implementation of training programs for faculty members and administrators.
- Coordination of multi-institution software and hardware acquisitions.
- Keeping up with the technical environment in order to identify relevant new hardware and software products.

The total needs of the State in these areas could not be satisfied by the small staff working alone. Rather, the staff would lead or coordinate task forces that draw upon individual institutional resources and personnel. Staff members would be selected both for their specific knowledge and experience and for their ability to bring them to bear in a cooperative organization.

Key relationships of the Coordinating Group to other agencies of the State would be as follows:

- The Director of the Group would report to the Executive Director of the Department of Administration, but would be delegated responsibilities for presenting budgets and plans to the Legislature and for communicating with heads of educational institutions.
- The Director would receive guidance on all matters relating to higher education computing from a representative Advisory Board.
- This Advisory Board would be formally recognized and given permanent status. It would also act as an advisor to the Executive Director of the DOA on matters that may require attention at this level.
- The presidents of the Colorado Colleges and Universities would maintain liaison with the Advisory Board and the Director for the purpose of exercising policy oversight.
- The Director would advise the Governor, the Joint Budget Committee, the Department of Administration, and the Colorado Commission on Higher Education with regard to computing in higher education.
- The Director would interact with the six separate governing boards of higher education on any matters pertaining to their computing activities.

4. Equipment

The Coordinating Group would not have operating responsibilities for any computing hardware. Individual institutions would rely on an appropriate mix of their own local equipment and computing services obtained from other sources. The Coordinating Group would encourage and support resource sharing through institutional or regional groupings, or by type of computing function.

5. Financing and Cost

The Coordinating Group would be funded as a part of the Department of Administration budget. It would need funds for salaries, office operations, training programs, and travel (the greatest portion of which would be within the State of Colorado). The annual cost of this consortium could be expected to range from $160,000 to $280,000. Software packages or other products acquired for multiple institutions would be financed on a cost-sharing basis by the using colleges and universities.

6. Development Plan

If this alternative were to be adopted, the Coordinating Group would be established by the Department of Administration. Its status would be recognized and the Advisory Board would be given authority through appropriate legislation. The Advisory Board would be appointed by the Associations of College, University, and Community College Presidents.

The Advisory Board would elect a chairman and an executive committee for the more detailed conduct of its business. A high priority task would be to advise the Executive Director of the DOA on the selection and appointment of a Director of the Coordinating Group. Once appointed, the Director should assemble a professional staff and assist in the process of upgrading institutional computing resources and provising educational support.

7. Advantages and disadvantages

The Coordinating Group would provide a mechanism for organizing and facilitating cooperative computing activities within Colorado higher education. It would lead in the development of a statewide plan based on inputs and trade-offs made by the users of computing in each of the colleges and universities.

The Coordinating Group would have as part of its mission support and advocacy functions for computing in higher education. Inputs from institutions would be summarized in a way that would permit trade-offs among alternative uses of resources within the higher education community. The primary responsibility for planning would reside where it is likely to be most effective -- with the institutions and those who are most knowledgeable and directly involved in assessing needs and priorities of higher education.

D. An Independent Operating Corporation

1. Introduction

A separate and independent corporation has been proposed as a solution to the problems of budgeting and long-range planning for computing in higher education in Colorado. An independent corporation would be a new type of enterprise for Colorado, and would offer a number of advantages for managing computing. A principal advantage would be that it could establish its own financing, and could therefore budget and plan for a period longer than the one year typical of most State financing. Capital expenditures could be recovered through normal usage charges, thus generating funds for replacement equipment without having to receive periodic capital appropriations. The corporation could also be more flexible in acquiring equipment and software by avoiding the formal review and approval process required of State agencies. It could offer services to other non-profit organizations and agencies of the State to expand its financial base, thereby increasing its capabilities for offering service to higher education.

An independent operating consortium could take two forms. One form would be that of a facilities management organization that assumes control of all computing resources, including equipment and personnel, throughout all of the universities and colleges in the State. Such a corporation could consolidate resources and the implementation of new computing service centers in ways designed to increase efficiency and cost-effectiveness. All colleges and universities would then be required to obtain computing services from the corporation in much the same way that they acquire electricity and communication services. The motivation for this approach would be to gain economies of scale in the purchase of equipment and in the supplying of services.

An alternative form of the independent operating corporation is a limited operating company that implements, staffs, and manages regional computing centers and provide services for institutions throughout the State on a contracted basis. Colleges and universities would retain responsibility for operating their own local equipment, but this equipment would be limited to relatively small minicomputers and microcomputers.

2. The Total Facilities Management Option

Governance. The independent corporation would be established by a legislative charter as a non-profit operating corporation responsible to a board of directors and having its own facilities and staff. It would be separate and independent from the State government. By statute all institutions of higher education would be required to purchase computing services from this corporation. Its board of directors would include representatives from institutions of higher education and such other members as would be appointed by the Legislature. Its income and expenses would not be included in the State budget, and its debts would not be a liability of the State. Any income in excess of expenses in any year could be carried forward to future years. The corporation would have the right to sell services to any non-profit or governmental organization.

Organization. The corporation would have responsibility for statewide planning of computing in higher education, as well as for the management of operating facilities throughout the State. The principle operating officer would be President, who would be assisted by a Vice President of senior stature. The staff would include groups responsible for planning, software development, educational services, and business and finance functions. It would have a personnel officer who would be responsible for staffing and career growth opportunities for all staff members of the corporation.

The regional operating facilities would each have their own managers and operating staffs. The staffs would be expected to remain in close contact with their clients on an outreach basis and not simply as passive providers of service. In addition to operating the regional center, each facility would have the systems software and maintenance staff needed to manage their particular type of computing equipment; it would not undertake major new systems or applications software development.

There would be an initial requirement for at least 15 professionals on the staff of the central corporate organization. Others would be needed at the regional facilities. Some compensating staff reductions could be made at the individual institutions, although it would be advisable to retain some personnel at the local level to provide technical support services at the campuses.

Regional facilities would be an essential component of the corporation. A likely configuration would include major facilities in Boulder, Fort Collins, Golden, Grand Junction, and Pueblo. Although located at or near the campus of a university or college, these centers would be operated by the corporation on behalf of institutions throughout the State. The centers would be linked by a communications network that would enable a user to go through the local center to access any of the other centers that might offer a unique service.

All institutions would have local processors that would provide remote job entry to the major facilities, as well as simple interactive computing. The number of local processors would vary with the size of the institution and with its educational and administrative computing needs. Some specialization of function within each major center is envisioned; such specialization could be in terms of the equipment vendor or the type of service offered (e.g., whether it was scientific computing or administrative data processing). It would be the responsibility of corporate management to provide the most cost-effective distribution of facilities, communications, and technical services. Differences in educational mission would be recognized so that services needed by each institution could be provided.

Financing and costs. At the time the corporation is formed there would be a paper turnover of all budgets, equipment, and personnel for computing at the various institutions of higher education. This would provide the initial resource base for the corporation. In addition, the corporation would work to establish lines of credit with regular lending organizations outside the State government.

Each year a rate schedule for all chargeable services would be established based on expected demand. These rates would then be used by the individual institutions in budgeting their computing activities through their normal budgeting process. Since the corporation would be independent, there would be no need on a short-term basis for the budgets for computing at the individual institutions to match exactly the expenses of the corporation. Although the lack of a guaranteed balance between income and expenses would create some risk for the corporation, it would be a healthy form of risk that motivates the corporation to plan carefully and compete for the business of the campuses and other non-profit organizations.

The initial incremental cost of this alternative would be the cost of supporting the central staff, a minimum of about $525,000 per year at the outset. Additional costs may arise through the conversion of hardware and software and increases in communication facilities. Over time these added costs might be offset through personnel reductions or sales of service to other agencies.

Development plan. If the concept of a non-profit corporation were adopted, the corporation could be established by the Legislature in the spring of 1979. By the summer of 1979, the President and the primary professonal staff should be appointed. In the fall of 1979, all existing computer facilities and staffs in higher education institutions would be turned over to the corporation without any major changes in their operations. During the fiscal and academic year 1979-80, the corporation's primary activity would be planning for the establishment of its major operating centers. In addition to operating the facilities currently in place, management would have to give high priority to planning for equipment replacement and upgrades so that installation could begin in 1980-1981. By the summer of 1982 it would be anticipated that all of the older equipment at separate institutions would have been replaced, major centers would be linked together by a communications network, and all computer services would be established on a corporate basis.

Advantages and disadvantages. The principal benefits of this approach would be to place higher education computing on a business-like basis and to achieve economies of scale in the provision of services, the purchase of equipment, and the use of personnel.

Despite these attractive arguments in favor of an independent centralized corporation, there is serious question as to whether a centralized computing organization could achieve its goals of providing cost-effective computing while remaining responsive to user needs. There is also a question of whether the corporation would be accepted by the institutions it serves, since such an approach runs counter to the history of institutional and governing board autonomy in Colorado. There is the further question of whether the initial added cost of half a million dollars per year could ever be reduced or offset by other economies or income. Experience in other states suggests that a centralized approach in conflict with a general climate of institutional autonomy is likely to run into major problems.

3. The Regional Centers Option

This concept is similar to the total facilities management option except that it is more limited in its scope. Under this option a corporation would be formed similar to the one described above, with a similar governance and organization structure down to the regional facilities. Below the regional centers, however, its jurisdiction would stop and the individual institutions would have control over their own local facilities. The institutions would retain their own computer center staff and their own equipment for local services and for accessing the major operating facilities of the corporation. The corporation would own and operate equipment in the major facilities, and provide central planning for software development. Although the separate institutions would retain ownership and the right to select local equipment, the equipment would generally be limited in its capabilities to providing interactive services and access to the regional facilities.

The advantages of this arrangement are several. An institution would retain some control over its local service. The local staff could represent the needs of its users when it deals with the central corporate staff. The local staff is also likely to provide a greater continuity of technical support than would a central organization.

A disadvantage of this concept is that some economies of scale might be lost by having local staffs and equipment partially redundant with the central staff and equipment. There would be a tendency on the part of an institution to build up its local capabilities and reduce its purchases of services from the central corporation, even if this course did not provide the most efficient source of computing.

VII. RECOMMENDATIONS

Recommendations for Computing in Colorado higher education are presented in three groups. The first group deals with changes in management practices and incentives; the second with the removal of serious resource deficiencies (some of crisis proportion); and the third addresses the governance framework in which computing is most likely to serve Colorado effectively.

The first group of recommendations will require very little extra funding. This fact should not detract from its importance; this group of changes in management practice is likely to have the greatest and most lasting impact of any of these being recommended. The changes will give Colorado the tools to avoid future problems with computing and will allow higher education to begin closing the gap between capabilities and requirements.

Colorado higher education has a reasonable and affordable level of demand for computing relative to its other educational requirements. Available computing services are currently below this level, and the gap appears to be widening. The recommendations in Sections A and C below will change this trend, and allow available capabilities to more nearly match reasonable requirements. The recommendations of Section B will provide a much needed and cost-effective head start to this process. The three groups of recommendations are largely independent; each may be considered or implemented separately. Group A, however, will provide a critically important framework for the exploitation of the other recommendations.

A. Management Practices and Incentives

1. Budgeting

Changes should be made in the way budgeting and funding for computing is handled. These changes will encourage institutions to make better decisions regarding the trade-offs between computing and other needs, will encourage improved financial management of computing, and will provide a more accurate and consistant picture of computing costs. They will allow the identification of computing costs with the functions being served. They will smooth computing costs, eventually reducing the need for large capital increments.

- Computing at each institution should be given auxiliary enterprise status. This change will permit computing to be funded on an appropriate long-term basis and will provide for carryover of funds from year to year. Where appropriate, reserves for equipment depreciation should be established or other methods used to smooth equipment acquisition costs. It should be noted that the establishment of auxiliary enterprises will in no way abrogate the role of the Legislature in appropriating computing funds. Funds will continue to be appropriated for all computing needs of each institution; these funds will in turn be used for the purchase of computing services from the auxiliaries. This will permit the institutions and the Legislature to have for the first time an accurate picture of the annual costs of computing by institution and by major programs.
- The full cost of computing should be reflected in the budgets of the computing auxiliaries, including the amortized value of capital cost.
- The general appropriations for computing at each institution should be made available for purchases of service from their own auxiliary or, when appropriate, from other shared sources.

2. Resource Sharing

A non-profit marketplace for the sharing of computing resources among institutions should be provided. It should offer incentives for sharing to both providers and users.

- Institutions providing computing resources to others (services, software, shared hardware, etc.) should be permitted to recover the full cost of these resources. The funds thus received by their computing auxiliary should be retained and applied to the expenses of the auxiliary. There should be no adverse impact on other aspects of the institutional budget (tuition cost calculations, for example, should not include the cost of services provided to others.)
- Institutions that wish to purchase external computing services should be permitted to do so within the limits of their available computing funds.
- Budgeting and accounting methods for the auxiliaries should make it convenient to organize joint ventures among institutions through purchase of services or jointly managed shared resources.

- The marketplace and sharing arrangements should permit institutions not only to work with each other, but, where appropriate circumstances exist, to share with private schools, county or community governments, or other non-profit organizations.

B. Correcting Serious Resource Deficiencies

A number of deficiencies exist in Colorado higher education computing that call for urgent correction. To allow them to continue would be counter-productive and would result in a waste of State funds. The following four situations are in the most urgent need of attention now:

1. Replacement of The University of Colorado Administrative Computer

The current IBM 370/145 used for administrative computing at the University of Colorado reached a point of total saturation long ago, and should be replaced. It can only provide turnaround times for administrative work measured in days or weeks, not minutes or hours. This situation produces large and costly inefficiencies, including a reduction of fifty percent or more in the effective use of programmers' time. Larger costs are incurred outside of the specific computing budgets; they result from delay and frustration in the management process and from the inability of administrators to respond to current demands for information.

This replacement has been frustrated in large measure by past accounting practices. No annual cost has been budgeted for the capital cost of the current machine, and no reserve has been created for its replacement. There is therefore an apparent need for a large capital infusion (or for rent or lease funds) well beyond the level of the current budget.

2. Replacement of Obsolete Equipment

The clearly obsolete equipment within State higher education institutions should be replaced with up-to-date equipment offering current-day capabilities and cost performance. The following needs are the most urgent:

- The two IBM 1401 systems at Trinidad should be replaced by a modern small computer and/or with services shared with another institution.
- The IBM 360/22 and IBM 360/30 systems at Adams, Fort Lewis, Mesa, and Western should similarly be replaced with modern equipment.

- The DEC/10 system at the Colorado School of Mines should be replaced or upgraded to permit the School to continue to offer the high quality of computing services that have been an important part of its programs for several years. The current equipment has been overloaded for at least two years and is saturated now to the degree that service quality cannot be maintained.

3. Augmentation of Existing Equipment

Older items of equipment that have continued usefulness should be examined for opportunities to achieve a significant improvement in performance at a modest incremental cost through augmentation with modern features or capabilities (memory, disk, communication devices, etc.)

C. A Higher Education Computing Coordinating Group

Of the alternatives consider in Section VI, the one recommended by the study team is the Coordinating Group described in subsection C. The Coordinating Group would be a small organization with a modest budget, a higher education advisory board, and a reporting relationship to the Department of Administration.

Reasons for preferring this alternative are the following:

- It would combine the ingredients of user control and institutional autonomy with statewide cooperation and voluntary resource sharing.
- It would be likely to receive broad support from higher education in Colorado.
- The additional cost of a new organization would be modest: while somewhat greater than the status quo, it is considerably less than that of an independent operating corporation.
- The Group would provide a framework within which the higher education community can "get its act together" and speak with one voice to the Legislature.
- It would provide a channel through which the Legislature can indicate to the higher education community as a whole what trade-offs are expected in making new investments in computing resources.
- It would provide an important source of information, assistance, and leadership not now available in Colorado higher education.

1. Feasibility.

The formation of the Coordinating Group would require a minimum of legislative action and would retain the existing channels of communication regarding computing between higher education institutions and the Legislature: the Group would be organized within the Department of Administration, which already has certain planning and budgeting functions for computing in higher education.

The feasibility of this alternative rests further on its acceptability and cost-effectiveness. Acceptability depends on both the willingness of institutions to participate in a cooperative planning and budgeting process and the willingness of the Legislature to respond to well supported plans and budgets; the basis for both is present in this recommendation. Cost-effectiveness similarly has two components, the effectiveness of the solution in meeting higher education computing needs and the costs of achieving the solution. The institutions believe, and experience elsewhere suggests, that the greatest probability for achieving effectivness is found in a solution that places responsibility for success with those with the most direct stake in achieving it. Costs include the added budget of the Coordinating Group, offset in part by the savings achieved through appropriate sharing of resources or more efficient use of equipment. In no case are these costs large, and the chances of offsetting savings is as large as offered by any other alternative. The costs of equipment replacement (part B above) are a factor as well, but exist independent of the organizational recommendation. Avoidance of these costs is not feasible under any alternative, and is in any case inconsistant with the common desire to achieve at least a minimum level of quality in Colorado higher education computing.

2. Governance

The Association of Public College and University Presidents and The Association of Community College Presidents meet separately and together periodically to consider matters of common interest. Their combined agenda has included higher education computing. A commitment to placing computing on firmer footing has been demonstrated by the support received from the Associations' Steering Committee that was established to assist with the current computing study. It is suggested that these Associations consider extending the Steering Committee to provide a focus for the on-going consideration of computing matters.

These Associations should place a review of higher education computing on their regular agendas twice each year, and should provide policy guidelines to the Advisory Board. The presidents should also make their views known to the Director of Higher Education Computing, and the Executive Director of the Department of Administration. These Associations should assume responsibility for appointing the Advisory Board upon recommendations from their member institutions.

The Higher Education Computing Advisory Board should be established to advise the Director of the Coordinating Group and the Executive Director of the DOA on all matters pertaining to computing planning, budgeting, and management within the coordinating responsibilities of the Group. The Director of the Coordinating Group should serve as an ex-officio member of the Board and should provide the necessary staff support.

Members should be recommended by the head of the individual campuses. Normally a member would be the individual to whom the campus director of computing reports. The Board would consist of one member per institution and a small number of additional members selected for their general knowledge of computing technology, applications, management, and financing. The Board should select its own chairperson and should meet quarterly. An executive committee, which would meet monthly for the conduct of on-going business, should be elected by the Advisory Board to represent the common interests of like institutions of the several governing boards.

The success of this new function will be critically dependent on the ability of higher education institutions to provide the primary input to the Coordinating Group regarding plans, budgets, staffing, facilities, and development programs. The Director and staff of the Coordinating Group, although formally a part of the Department of Administration, should view themselves as representing the needs and the priorities of the higher education community as provided to them by the Advisory Board, its chairman, and its executive committee.

Among the first actions of the Board should be the drafting of by-laws and the election of the small executive committee. Additionally, the Board should be prepared to advise the Executive Director of the DOA on the selection of the Director of the Coordination Group.

The Director of the Higher Education Computing Coordinating Group should be selected by the Executive Director of the Department of Administration with the advice and consent of the Advisory Board. The Director will in turn select the staff and make the assignments necessary for carrying out the functions of the Coordinating Group.

The Director should be a senior individual experienced in higher education. An appropriate background may include substantial computing management responsibilities, administrative experience in higher education, and faculty experience in a relevant discipline. Experience in planning and budgeting and in working with faculty and administrative committees would also be useful.

The tasks of leadership and coordination require that the Director be selected for skills of pursuasion, tact, and diplomacy. The Director's credentials should help to establish a high degree of credibility with institutions and with others in State government. The Director must be sensitive to the very diverse nature and needs of the institutions across the State. Experience with large and small institutions, and with large and small computing centers, would be helpful.

The Higher Education Computing Coordinating Group should be formed within the Department of Administration. It's Director would be responsible to the Office of the Executive Director of the DOA. The group should be organizationally separate from the existing division of ADP within the DOA, and would have independent and distinct functions. To combine this group with the Division of ADP would create an internal conflict of interest between advocacy and coordinating tasks and those of audit, acquisition approval, and budget review. It would be appropriate, however, for some of the funding and staff for the Coordinating Group to come from the Division of ADP.

The need for a separate group for higher education is important because of the differences in the roles and purposes of computing in colleges and universities compared to state agencies. Higher education has a wide spectrum of needs beyond those of data processing. Research and teaching involve many diverse activities requiring special knowledge and experience at the state-wide coordinating level.

3. Functions of the Computing Coordinating Group

The Coordinating Group would be responsible for the following functions:

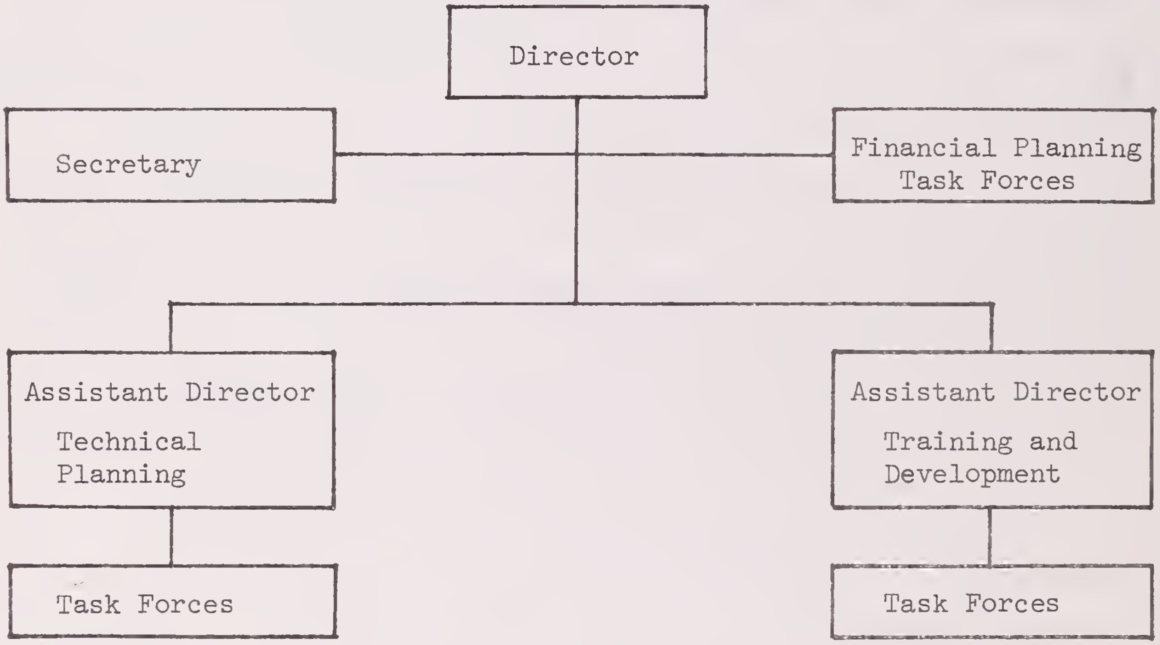
- Working cooperatively with higher education institutions to develop comprehensive long-range plans for computing in higher education.
- Developing budgets for computing in higher education.
- Presenting plans and budgets for computing in higher educaton to the Governor and the Legislature.
- Encouraging and promoting computer resource sharing in higher education.
- Providing or facilitating training for faculty on the use of computing in instruction.
- Providing or facilitating programs for computer center staff development.
- Encouraging and facilitating the establishment of a higher education Computing Center Directors Council.
- Advising institutions and their computing center personnel on matters of computing technology, management, and applications.
- Providing coordination for multi-institution acquisitions of hardware and applications software packages.
- Developing data communication plans that would allow for cost-effective computer resource sharing.
- Keeping abreast of technical developments for relevant new hardware and software products and sharing this information with the institutions.
- Providing continual support for the provision of computer services at all institutions of higher education in Colorado.
- Advising the Department of Administration, the Colorado Commission on Higher Education, governing boards, institution presidents, and other agencies related to higher education on all matters concerning the provision of computer services in higher education.

In addition to the Director, the Coordinating Group should have at least two other professionals selected for experience in technical and financial planning and the development of technical training programs. An optimum staff would consist of the Director, an Associate Director, three professionals, and a support staff of three persons.

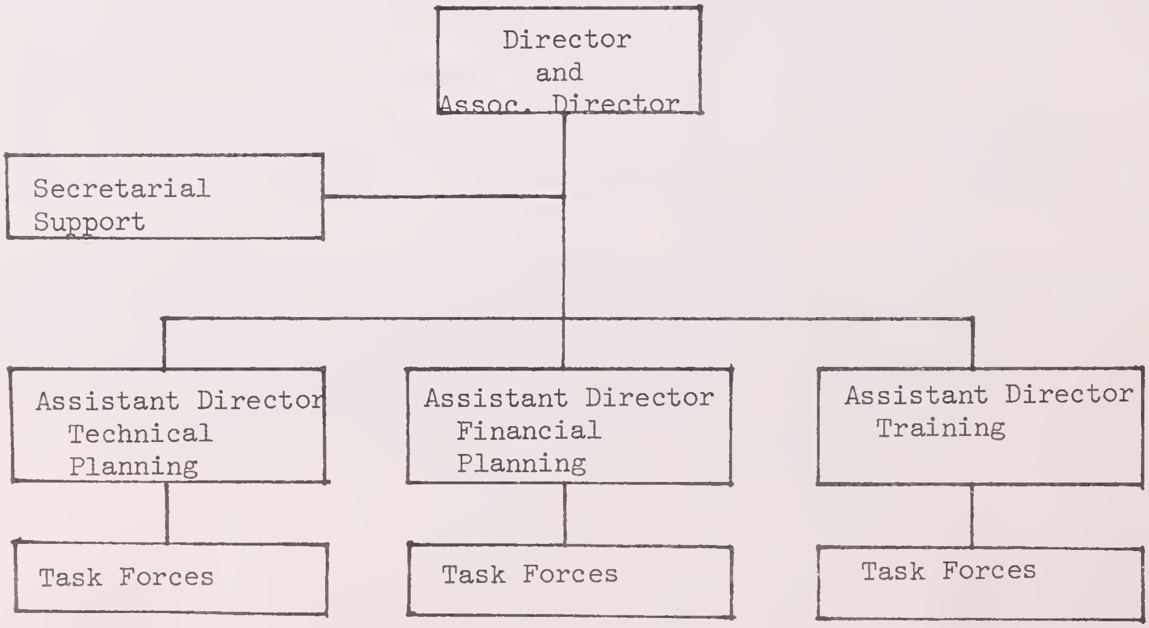
The work of the Coordinating Group would be carried out generally through task forces made up of personnel from the institutions of higher education. This arrangement would serve the combined purposes of keeping down the costs of the coordinating staff and increasing the involvement of the individual institutions in the planning process.

The organization of a minimum and an optimum staff are shown in the chart below.

Minimum Staff Organization


Director
Secretary
Financial Planning Task Forces
Assistant Director Technical Planning
Assistant Director Training and Development
Task Forces
Task Forces

Optimum Staff Organization


Director and Assoc. Director
Secretarial Support
Assistant Director Technical Planning
Assistant Director Financial Planning
Assistant Director Training
Task Forces
Task Forces
Task Forces

4. Relationship of the Division of Automated Data Processing to the Coordinating Group

The Division of Automated Data Processing would continue to approve the purchase of computing equipment and services for higher education upon recommendation of the Director of the Coordinating Group. In addition, the Division of ADP would conduct audits of higher education computing centers and prepare reports on the use, cost, and inventory of computing equipment in colleges and universities. In short, the Coordinating group would serve as the planning and support organization for computing in higher education, while the Division of Automated Data Processing would continue to be responsible for control and audit.

5. Legislation

The establishment of the recommended governance structure and the changes in funding and budgeting procedures could apparently be accomplished administratively by the Department of Administration. The changes are not major and have precedent in other actions -- for example, creating revolving accounts or re-organizing the responsibilities of the ADP component of the DOA.

Proceeding through the legislative channel has several advantages, however. The introduction and discussion of the authorizing legislation would provide an opportunity for the Legislature to learn more about the special contribution of computers to higher education. The opportunity would also exist to emphasize the fact that the recommended changes would strengthen legislative budget initiatives through the provision of a true annual cost picture that could be related to program needs and priorities.

Other important reasons exist for acting through the legislative process. It is essential to the success of the new organization that it has the status and permanance appropriate to its importance. The policy oversight role of the Presidents' Associations should be made explicit and the representative Advisory Board should be given official recognition. The special role of the Director of the Coordinating Group within the DOA, having responsibilities independent of those of the Division of ADP, should also be recognized. These steps will allow the new structure to continue to serve through changes of administration and leadership of the DOA.

A potential model for the appropriate legislation is found in House bill number 1725, introduced to the Fiftieth General Assembly of the State of Colorado in 1975. This bill authorized the establishment of centralized services, created the necessary revolving fund, and set the precedent for full cost charge-back for the services provided. An action in this pattern, combined with the appropriate recognition of the governance and coordinating structure, would provide a firm basis for successful coordination of computing within higher education.

Essential points that should be included in the authorizing Legislation are:

- Establishment of the principle that this group would be guided by the Presidents' Associations through a representative Advisory Board that provides inputs to the plans, budgets, staffing, facilities, and development programs to be proposed and implemented by the Coordinating Group.
- The planning and support functions of the Coordinating Group should be made explicit and distinct from the audit functions of the Division of ADP. The role of the Group as representative of the computing needs of higher education to the Legislature should be made specific.
- Consideration should be given to the treatment of computing as an auxiliary enterprise so that income, expenditures, and carry-over funds can be treated independently of the institutional budget coming from the general fund.

6. Finances, Costs and Budget

Financial support for the Coordinating Group would be by direct appropriation to cover salaries, office operations, training program materials, and travel (most of which would be in-state). The costs of task force activities and any multi-instituiton software or hardware acquisitions would be borne by the institutions.

The annual budget for the Coordinating Group for the first full year of operation with a minimum staff would be:

Salaries and benefits (20%)	$134,000
Office operations	10,000
Training program materials	4,000
Travel	12,000
	$160,000

For the optimum staff, the budget would be:

Salaries and benefits (20%)	$240,000
Office operations	16,000
Training program materials	4,000
Travel	20,000
	$280,000

In addition to the formation of the Coordinating Group, this study recommends the up-grading of equipment in many institutions. While that has not been detailed in this Report, the figure over three years (1979-1982) would be in the range of $1,400,000 to $1,900,000.

The findings of this Report do not indicate major opportunities to reduce costs in future years; higher education computing budgets have been at a bare bones level and resources have not been kept up to date. If resources comparable to those of other states are to be provided, costs will go up. Coordination will add a small increment over and above the budgeted funds for institutional computing. This expenditure for coordination would be offset in part by savings from the avoidance of redundant, superfluous, or poorly used resources.

7. Transition and Implementation

Legislation should be introduced as soon as possible for the establishment of auxiliaries and recognition of the governance structure. The members of the Advisory Board could be selected in advance of the formal passage of the enabling legislation. The Department of Administration should include the Coordinating Group and its funding in the next budget presentation. With an early start, the position of Director can be filled by the fall of 1979. Changes in management practices and incentives (VII A above) should begin with the next fiscal year.

With the appointment of a Director and the establishment of a professional staff, the Coordinating Group should work with the Division of ADP to assure a smooth transition to the new process of planning and budgeting for computing in higher education.

Establishing the Colorado Higher Education Computing Coordinating Group would be a modest but important step. It would not bring about major disruptions in the present mode of operation, but would instead move higher education step-by-step toward the improved use of computing. This is surely a practical and worthy goal for Colorado.

APPENDIX

COMPARISON WITH OTHER COMPUTING CONSORTIA IN PUBLIC INSTITUTIONS OF HIGHER EDUCATION

Introduction

Experiences in other situations provide some useful lessons that can help in organizing cooperative computing arrangements within Colorado. Although each set of circumstances is sufficiently different that precise generalizations are impossible to make, some legitimate general assertions can be made about the conditions that are likely to lead to successful cooperative arrangements and those conditions that often cause problems. The choice of a structure and governance mechanism for higher education computing in Colorado can thus more easily avoid the negative conditions and reinforce the favorable circumstances.

Several limitations must be kept in mind when interpreting the experiences in other jurisdictions, however. For one thing, it is usually not possible to pinpoint the favorable or unfavorable circumstances that led to success or failure. Indeed, it is often not easy to make a judgment about whether a given cooperative arrangement is in fact a success or failure. Usually it has both successful and unsuccessful aspects, and one person's evaluation of the outcomes may differ markedly from another's.

A wide variation exists in the missions and governance structures among public institutions of higher education. The differences may not always be obvious, however. For example, it is often the case that the formal governance structure of a university differs in important respects from its real decision making structure. Characterizing subtle power relationships in order to draw general conclusions about the likelihood of success or failure is a hazardous undertaking.

Notwithstanding these caveats about the risks of applying experience from other locations, it should nevertheless be said that surprisingly uniform conclusions emerge from a review of cooperative computing arrangements. Even in the face of differences in such matters as mission, governance, financial support, and relative emphasis on public versus private institutions, it is still possible to identify circumstances that are favorable or unfavorable to successful cooperation among colleges and universities.

The purpose of this Appendix is to draw such conclusions from the experiences of a few selected public systems of higher education. One system -- the Georgia University System Computing Network -- is discussed in special detail because it offers a particularly useful model for Colorado. Other cooperative arrangements are discussed in considerably less detail.

GEORGIA'S UNIVERSITY SYSTEM COMPUTING NETWORK

Organization

The University System of Georgia is composed of 33 state-supported institutions of higher education. Of these institutions, four are universities, thirteen are four-year colleges, and sixteen are junior colleges. The institutions are under one Board of Regents. The chief executive officer of the Board of Regents is the Chancellor, with various functional areas handled by Vice Chancellors and Assistant Vice Chancellors. One of these individuals is responsible for computing systems.

In the later 1960's, the University System established a mechanism for developing long-range and short-range plans for computing. Four major steps were taken:

1. The appointment of the Assistant Vice Chancellor for Computing Systems with the primary charge to coordinate computing and computing services in the entire University System.

2. The appointment of one person (a campus coordinator) to be in charge of all computing on each campus.

3. The formation of the Regents Management Information System Group to coordinate those administrative systems that would be used by all institutions in the system.

4. The formation of the Resource Planning and Evaluation Committee (RPEC) to provide planning in all areas of computing.

The Resources Planning and Evaluation Committee is composed of seven members with the Assistant Vice Chancellor as chairman. Members of the committee are representative of the varying size institutions as well as the Regents

MIS Group. They are charged with the responsibility for developing plans for computing in the State and the approval or disapproval of all hardware installed at any institution. They also have the power to appoint special task forces to solve special problems.

The campus coordinator is responsible for the approval of all computing hardware ordered from his campus as well as the operation of the campus computing center. Computing hardware approved by the campus coordinator is then passed to the RPEC, through the president of the institution, for its action. The approvals are then passed to the State EDP Committee for final approval.

Implementation of a Statewide Plan

In 1969, the RPEC began developing a statewide plan for computing in higher education. The basic plan, although updated each year, is still in place. This plan called for the following major actions:

- Establish a major computing center on the campus of each of the three larger institutions, the University of Georgia, Georgia Institute of Technology, and Georgia State University. In addition, establish an installation at the Medical College to be used for hospital management and medical records.

- Establish one center to serve the needs of the smaller institutions.

- Install computing hardware of varying size at the other institutions in order to meet many of the administrative needs on that campus. Additional needs would be obtained from the Network Central Site or from one of the other three centers.

- Organize a University Network Executive Committee to be concerned with the operating policies and procedures at the Central Network Site.

- Begin the development by the Regents MIS Group of certain standard administrative software to be used by all institutions in the University System. This software could be of two types: one designed for the smaller institutions, and one for the larger and more complex institutions.

- Appoint a special task force to design an appropriate communication system that would link all CPU's within the system, thereby giving access to all CPU's by any campus.

- Provide a central site staff that would provide consulting to all network users as well as technical support to the smaller institutions.

- Encourage the sharing of all computing resources, both hardware and software, within the University System.

- Encourage the sharing of ideas through annual, or more frequent, meetings and workshops.

The basic plan was prepared in 1970 and approved that same year by the Board of Regents; additional items have been added to the plan each year.

Services Provided

The University System Computing Network includes the following services:

- Batch computing
- Interactive computing
- Educational support
- Technical support
- Programming and analyst support
- Standard administrative software
- Computer test construction
- CAI languages and lessons
- Circuit riders
- Computer bibliographic search services
- Variety of computer languages
- Variety of computing hardware facilities
- Library automation

Factors of Success

To many people, the Georgia plan is considered successful. The success can be attributed to the following reasons:

- Each institution has retained its own autonomy, allowing it to choose, in large measure, the amount of computing services it wishes to maintain on its own campus or obtain from the other sites.
- Institutions are encouraged not to duplicate services that can be obtained from another institution. This is accomplished by the RPEC through its peer review and approval authority.
- Excellent technical and educational support is provided from the Central Site as well as from other institutions.
- Services that cannot be obtained locally are obtained over the network.
- Each institution has a voice in the operation of the Central Site and a complete voice in the operation of its local site.
- The sharing of ideas by all institutions is fostered by at least two meetings per year of all computing personnel, and by frequent visits made by Central Site personnel to all institutions (150 such visits last year).
- Users and administrators feel that they have someone looking after their interest, by the interface of the Assistant Vice Chancellor with the State EDP Committee as well as other State agencies.
- More computing hardware and supplies are obtained for the money because of bulk contracts.
- The appropriate administrators are involved in the design of standard software.

How Georgia Differs from Colorado

It is useful to contrast conditions in Georgia with those in Colorado in order to determine whether Georgia's success can be duplicated in Colorado. The major differences are:

- All institutions are under one Board of Regents.
- Funding is appropriated as a lump sum to the Board of Regents.
- The full cost of computing is reflected in the budget of each institution as well as in the budget of the Board of Regents.
- Each institution is billed for resources used at the Central Site and all other sites.
- Each user is billed for the resources used at any site.
- Plans are made and reviewed by people concerned with, and a part of, higher education.
- There are built-in incentives to share.
- Each institution has considerable autonomy with respect to the allocation of funds for computing and how computing dollars will be spent.
- The total computing cost in the University System is approximately $12,000,000 per year.

OTHER COOPERATIVE ARRANGEMENTS

New Jersey Educational Computer Network

The New Jersey Educational Computer Network (NJECN) evolved out of two earlier attempts to share computing services in New Jersey higher education. A beginning structure at Rutgers University was funded by the National Science Foundation, and was known as the Educational Computing Center. Following this funding period, a transitional organization was established as a not-for-profit corporation. Its charter was later amended to include all of the computing services for Rutgers University as well as the state and community colleges, and it became NJECN.

The official mission of NJECN is to make available and encourage the use of computer power to institutions of higher education in New Jersey, and to provide computer services to support and enrich academic and administative programs. The by-laws of NJECN specify a Board of Directors representing six sectors of higher education according to a formula based on the level of dollar commitment to the expense budget. Rutgers University has six voting members, the state colleges have two, and four other institutions and groups have one each. The Department of Higher Education is represented by one non-voting member. The advisory structure includes a Planning and Technical Committee. There are also representative groups of Academic Campus Coordinators, Registrars, and Financial officers.

The principals commit to a level of financial support for the network each year, including any deficits. The users are solicited in December for their needs for the following fiscal year. The Finance Committee of the Board and the Planning and Technical Committee review the resulting proposal for budget and resources made by the Executive Director and determine a rate structure and configuration of resources.

The services provided by NJECN include a wide range of hardware services offered on an IBM 370/158 and an IBM 370/168. At the user institutions there are 41 RJE terminals and 490 timesharing terminals. There is an academic software support activity and an ADP software development group.

NJECN has been described as a "shotgun marriage" between the University, the state and community colleges, the Institute of Technology, and the Medical/Dental School. The disparities of size and program between these institutions has made true cooperation difficult to achieve. A special problem has been a serious devisiveness stemming from the rivalry between Rutgers and the group of state colleges. Most institutions -- especially Rutgers -- feel that NJECN does not serve their particular needs or give them alternative sources of computing.

The role of NJECN currently seems to be changing as several institutions -- including the Rutgers administrative function, the Institute of Technology, and the Medical/Dental School -- move to acquire significant computing resources of their own. There has also been a decision to place distributed processors in the state college campuses, which will further dilute the centralized operating role of the network.

City University of New York

CUNY operates a centralized computer center that serves 22 campus sites. RJE terminals provide the primary means of access to the central machine, an Amdahl 470V/6 (roughly equivalent to an IBM 3033). Increasingly, interactive terminals are also being used. A total of about 600 have been installed at the campuses, and as many a 200 may be connected at a given time.

A distinctive feature of the system is that it serves both administrative and academic users. Most administrative applications are processed in batch fashion, but advanced on-line systems are increasingly being installed. A sophisticated priority system is used to allocate hardware resources, in which users can obtain priority treatment for a premium charge. This scheme has made it possible to serve a wide veriety of user and applications without serious problems of conflict between them.

Most students use a special job class for fast turn-around (less than 10 minutes) of batch jobs. The individual institutions are not charged directly for this service in order to encourage efficent use of the computer for academic work and to avoid unnecessary red tape for students to gain access to the system.

The CUNY system is relatively centralized. Although some small computers exist on the campuses, most computing is obtained from the central site. Any addition to local capacities must be approved by the senior official to whom the central computing center reports.

The system is generally regarded as successful. Based on a study of alternatives available to CUNY, the centralized approach was estimated to cost only one-sixth of the amount that would have been required to offer comparable service from separate campus machines. Some of this savings is due to the close proximity of all campuses, substantially reducing communication costs compared to the typical statewide or regional center. An important source of saving also comes from the development of common administrative applications that serve multiple institutions. Most campuses would not give serious consideration to establishing services in competition with the central system (even if this were allowed). The success of the CUNY system is due to several factors:

- It serves a relatively small geographical area, greatly facilitating data and person-to-person communications.

- It has a history of providing quality service at a cost that individual institutions cannot match.

- Sufficent central control exist, in both computing and general administration, to encourage joint activities (e.g., common administrative software).

CONCLUSIONS

Based on the experiments discussed in the previous section, the following conclusions emerge:

- A strong contrast between the organization of computing and other management functions usually leads to severe problems. Thus, a centralized approach to computing within a generally centralized structure is likely to be successful. Within the City University of New York, for example, a relatively high degree of centralization in computing has proven to be successful because it conforms with the general management style of CUNY. In contrast, New Jersey has experienced great difficulty in developing a statewide network because of the lack of a strong central focus in higher education.

- The incentive system must encourage sharing and cooperation if success is to be achieved. For example, a supplier must be able to recover its full costs of serving external users, and users must not be penalized by using a shared resource by having to pay real money for an external source and "funny money" for an internal source.

- High quality service from a central facility is a necessary (if not sufficient) condition of success.

- Voluntary sharing, in which both parties see the arrangement as serving their interest, is likely to be much more successful than forced sharing.